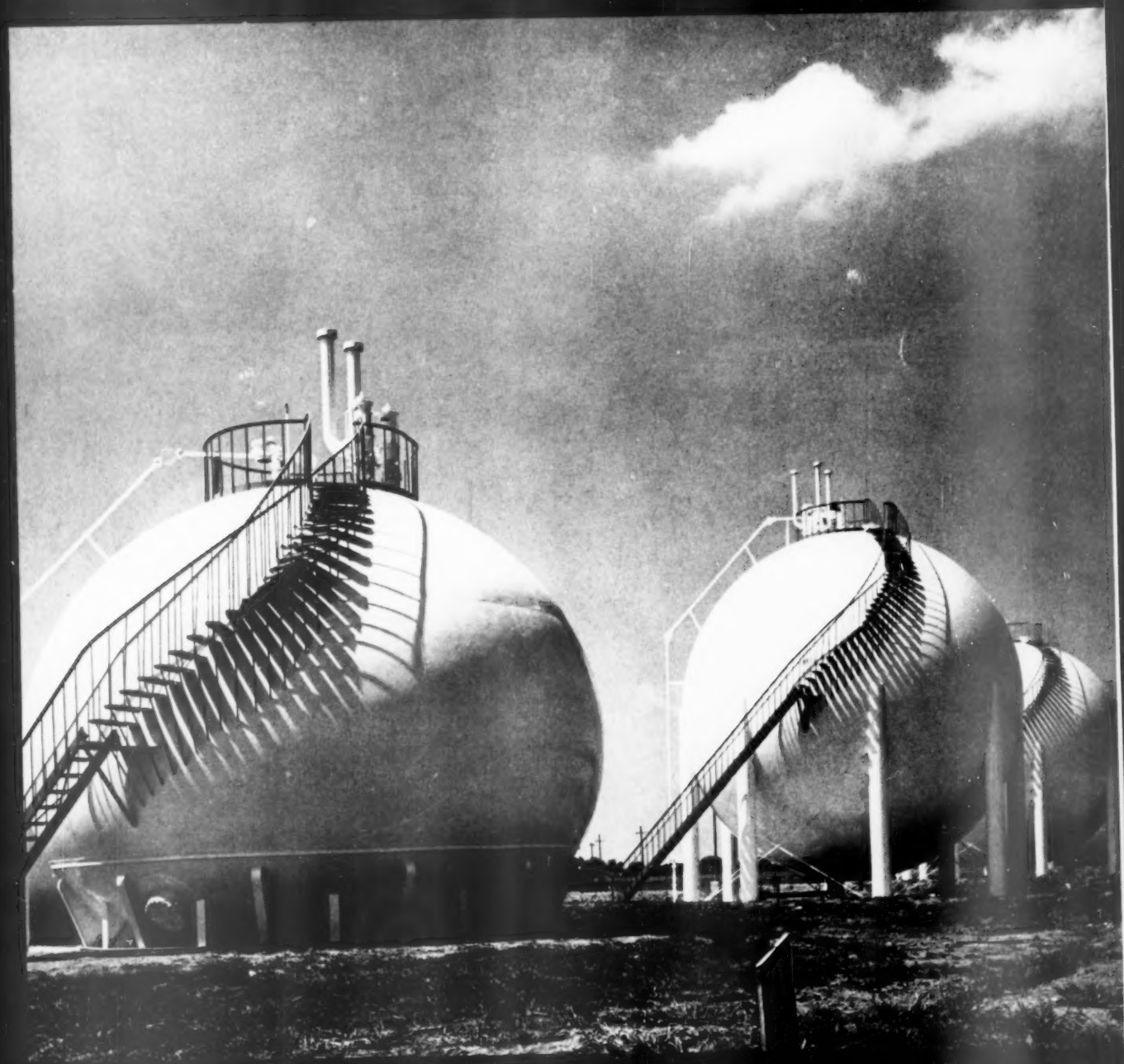
JOURNAL OF

Petroleum Technology



NOVEMBER, 1953

OPERATIONS IN THE USA

THE CUSTOMER IS KING! SERVICE THE BY WORD

25 SERVICES 1 TRIP TO THE WELL

THE OLD DUTCHMEN SAID, 'SPEAKING IS SILVER AND SILENCE IS GOLD' SCHLUMBERGER SERVICE IS HELD IN STRICT CONFIDENCE

TIME IS MONEY AT THE WELL PRINTING AND DELIVERY OF COMPLETE PRINTS AT THE WELL

THE OLD DUTCHMEN SAID: 'DE COST GAET VOOR DE BAET UIT' (THE EXPENSES PRECEED THE PROFIT) SCHLUMBERGER BELIEVES THAT MONEY SPENT ON RESEARCH PAYS IN THE LONG RUN

PREVENTIVE MAINTENANCE

30 SHOTS IN THE WALL OF THE WELL AT THE WILL OF THE OPERATOR: THE SAMPLE TAKER

SELECTED ENGINEERS

THE FIRST AND THE LAST WORD IN LOGGING

EVERY LOG A QUALITY PRODUCT

THE OLD DUTCHMEN SAID: 'Throw a smelt to catch a pike' THE PRICE OF A SCHLUMBERGER IS NEGLIGIBLE COMPARED TO THE LOSS OF AN OIL-FIELD

WELL QUALIFIED PERSONNEL

NIGHT AND DAY

Schlumberger service with a smile

THE OLD DUTCHMEN SAID: 'Don't buy turnips for lamony' YOU CAN DEPEND ON SCHLUMBERGER

ANYWHERE

24 HOURS ROUND THE CLOCK

ANY TIME

WALLS CHANGED, GUNS HAD TO CHANGE TOO! SCHLUMBERGER EQUIPMENT KEEPS STEP WITH PROGRESS

ANY WAY!

ENGINEERS TRAINED BY EXPERTS

WHY OPERATORS PREFER SCHLUMBERGER

Schlumberger Well Surveying Corp. • Houston, Texas

RESEARCH

Life Preserver for Tideland Production

Pioneer tool pushers were transplanted sailors, taking land jobs in the first Pennsylvania oil fields. Right behind them came their heavy nautical equipment so easily adapted to drilling work. That's where we got our rigs, masts, logs, catheads, reels, etc. Offshore drilling now rounds out the cycle. And helping the industry get back its sea legs is Halliburton's energetic Marine Research. Since 1947, when the first cementing boat tied up to a Louisiana dock, Halliburton has devoted much effort to developing marine production improvement techniques. Today there are 14 vessels flying Halliburton's flag in the coastal canals, inland waterways, wherever wells are drilled. Such research is a life preserver for tideland production, helps recover this needed oil at lower costs.

PERPETUAL PROGRESS IN PRODUCTION IMPROVEMENT TECHNIQUES

HALLIBURTON OILWELL CEMENTING COMPANY

New!

Baash-Ross "PB" Quick Change PRODUCTION BLOCK

Quickly Convertible to one or two sheaves!

Baash-Ross—pioneers of modern unitized Block-and-Hook designs and many other important Block advancements—now brings you *another* vital development in this field . . .

A Block (with choice of connector units) that can be quickly converted to one sheave or two sheaves, depending upon requirements—*without re-reeving the lines or making complicated changes!*

Use it as a *two*-sheave Block when pulling tubing and doing other work where the added capacity of a four-line string-up is needed.

Then, by simply removing a few bolts, the Block can be divided, one sheave anchored in a corner of the rig without even re-reeving the lines (see left, below) and you have a fast-acting *single* sheave Block for pulling rods and other light work where fast Block travel is desired.

As a *single*-sheave unit the Baash-Ross "PB" has more weight than conventional single-sheave blocks—falls faster, hangs straight, doesn't "wander" when running empty.

Available Through Leading Supply Stores

What about line reeving?

Baash-Ross has simplified that, too. Each sheave unit can be easily opened to expose the sheave without removing covers, as shown at right. Lines are simply *laid* in place—can be left looped in rig between jobs to save time and eliminate dangerous crown reeving each time a job is set up.

Wide choice of Connector units

To increase still further the unusual adaptability of Baash-Ross "PB" Blocks, they can be equipped with any of a wide choice of Connector units . . . Becket—spring-loaded Link Adapter—spring-loaded Standard Hook—or spring-loaded Oversize Hook. Both the Hooks and Link Adapter are free-swiveling in a full 360° circle, or can be quickly locked in any of 8 equi-spaced positions.

Baash-Ross "PB" Quick Change Blocks are designed throughout for long trouble-free life. Get full details on this new development from your nearest Baash-Ross representative. Or write direct!

Baash-Ross

TOOL COMPANY *Our 34th Year*

GENERAL OFFICES: 5512 SO. BOYLE AVE., LOS ANGELES 58
OKLAHOMA CITY • HOUSTON 20 • ODESSA • CASPER
Export Offices: 250 Park Ave., New York 17

JOURNAL OF
Petroleum Technology

EDITORIAL BOARD
CLAUDE R. HOCOTT
PAUL R. TURNBULL
THOMAS C. FRICK

EDITORIAL DIRECTOR
JOE B. ALFORD

EDITOR
JESS E. ADKINS

MANAGING EDITOR
VIRGINIA BEILHARZ

EDITORIAL ASSISTANTS
BEKY YODER
HELEN TAUBMAN
MURIEL RALPH

ADVERTISING MANAGER
RICHARD C. WIPPERMAN

EASTERN ADVERTISING SALES
LEWIS V. HOHL
205 E. 42nd St., New York, N. Y.

JOURNAL OF PETROLEUM TECHNOLOGY is published monthly by the Petroleum Branch, American Institute of Mining and Metallurgical Engineers, Inc., at 800 Fidelity Union Bldg., Dallas 1, Tex. Entered as second class matter at the Post Office at Dallas, Tex. Domestic Subscription: North, South and Central America, $8; foreign, $10; to AIME members, $6 (or $4 if in combination with subscription to either Journal of Metals or Mining Engineering). Single copies, 75 cents; special issues, $1.50. Registered cable address, AIME. Printed in USA. Copyright 1953 by American Institute of Mining and Metallurgical Engineers, Inc.

Official Publication of the

PETROLEUM BRANCH
American Institute of Mining and Metallurgical Engineers, Inc.

800 Fidelity Union Bldg.
Dallas, Texas

Statements and opinions contained in the JOURNAL OF PETROLEUM TECHNOLOGY are, unless otherwise indicated, attributable only to the author, and do not necessarily reflect the views of the AIME, its officers, committees or other agencies.

The AIME also publishes:
Mining Engineering
Journal of Metals

OFFICERS of the PETROLEUM BRANCH

Chairman
Claude R. Hocott
Humble Oil and Refining Co.
Houston, Texas

Vice-Chairmen

John P. Hammond
Amerada Petroleum Corp.
Tulsa, Okla.

Basil P. Kantzer
Union Oil Co. of California
Los Angeles, Calif.

EXECUTIVE COMMITTEE

Thomas A. Atkinson
Socony-Vacuum Oil Co.
Casper, Wyo.

Roland Gouldy
Hull-Silk Repressuring Assoc
Wichita Falls, Texas

John S. Bell
Humble Oil and Refining Co.
Los Angeles, Calif.

E. N. Van Duzee
Shell Oil Co.
New York, N. Y.

Thomas C. Frick
Atlantic Refining Co.
Corpus Christi, Texas

G. L. Yates
Amstutz & Yates
Wichita, Kansas

Paul R. Turnbull
Vaughan, Zoch & Turnbull
Corpus Christi, Texas

Paul R. Schultz
Stanolind Oil & Gas Co.
Tulsa, Okla.
Representing M.E.D.

Charles R. Dodson
Stanley, Stolz & Dodson
Los Angeles, Calif.
Representing M.I.E.D.

Treasurer
W. E. Stiles
Buffalo Oil Co.
Dallas, Texas

Executive Secretary
Joe B. Alford
AIME
Dallas, Texas

Counsel
Robert E. Hardwicke
Hardwicke, Haddaway & Pope
Fort Worth, Texas

COMMITTEE CHAIRMEN and VICE-CHAIRMEN

Admissions
J. H. Sullivan
Atlantic Refining Co.
Dallas, Texas

Advertising
Bruce Barkis
B & W, Inc.
Houston, Texas

Economics
Douglas S. Ball
Petroleum Consultant
Washington, D. C.

Education
John C. Calhoun, Jr.
Pennsylvania State College
State College, Pa.

Membership
M. B. Penn
Mid-Continent Petroleum Corp.
Tulsa, Okla.

Nominating
Paul R. Turnbull
Vaughan, Zoch and Turnbull
Corpus Christi, Texas

Publications
R. A. Morse
Stanolind Oil and Gas Co.
Tulsa, Okla.

Student Activities
W. S. Morris
East Texas Salt Water Disposal Co.
Kilgore, Texas

Production Review
R. B. Gilmore, Chairman
DeGolyer and MacNaughton
Dallas, Texas

Milton Williams, Domestic
Humble Oil and Refining Co.
Houston, Texas

A. H. Chapman, Foreign
Arabian American Oil Co.
Washington, D. C.

Technology
William H. Justice, Chairman
La Gloria Corp.
Corpus Christi, Texas

Preston E. Chaney, Drilling
Sun Oil Co.
Beaumont, Texas

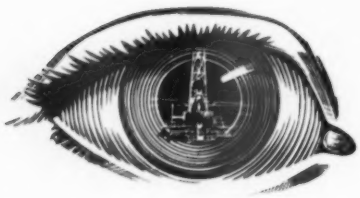
Don C. Harlan, Production
The Texas Co.
Houston, Tex.

W. F. Speaker, Gas
Magnolia Petroleum Co.
Dallas, Texas

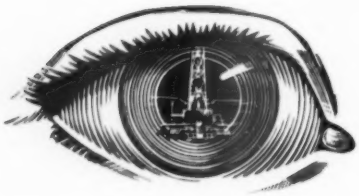
Clarence C. Liedholm, California
Signal Oil and Gas Co.
Los Angeles, Calif.

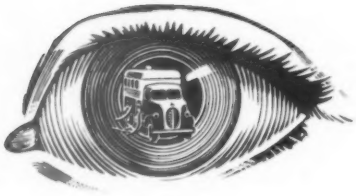
OFFICERS OF THE AIME

President, Andrew Fletcher; Vice-Presidents, J. L. Gillson, O. B. J. Fraser, J. B. Morrow, L. E. Elkins A. B. Kinzel and T. B. Counselman; President-Elect, L. F. Reinartz; Past-President, Michael L. Haider; Treasurer and Controller, G. I. Brigden; Secretary, E. H. Robie.



drill...





with both eyes open!

Use Core Lab's Well Logging Service . . . . Each foot drilled is logged for drilling time . . . Cuttings are minutely analyzed for hydrocarbon concentration indicating oil and gas . . . Gas concentration in drilling mud is measured continuously to reduce the possibility of blowouts . . . Physical characteristics of mud (weight, viscosity, water loss) are measured each tour . . . Data on cuttings and mud are plotted versus depth for interval logged . . . Stray pays are picked up when encountered, while anticipated productive zones are pin-pointed without unnecessary "pre-coring". The same Core Lab crew and portable equipment are immediately available to perform On-Location Core Analysis at no extra charge. *Drill with both eyes open. Drill with Core Lab's Well Logging Service.*

CORE LABORATORIES, INC. ● IN ALL ACTIVE AREAS

Dallas, Houston, Corpus Christi, Midland, Abilene, San Antonio, Tyler, Wichita Falls, Lubbock, Oklahoma City, Ft. Worth, Great Bend, Shreveport, Lafayette, New Orleans, Natchez, Bakersfield, Denver, Sterling, Worland, Williston, Billings, El Dorado, Hattiesburg, Farmington, Lovington, Calgary, Edmonton.

CORE LAB

WELL LOGGING SERVICE

JOURNAL OF
Petroleum Technology

Vol. V NOVEMBER, 1953 No. 11

CONTENTS

Editorial Features — Section 1

Integrating Well Completion Practices, by H. F. Hopkins . . 13

Technical Note: An Explanation of the Yuster Effect, by P. H. Scott and Walter Rose 19

Technical Note: The Steady-State Flow of Gas Through Glass Capillary Tubes, by George C. Wallick 20

Record Attendance Set at Branch Fall Meeting 26

Petroleum Transactions

Description and Analysis of an Efficient Continuous-Flow Gas-Lift Installation, by A. F. Bertuzzi, J. K. Welchon, and F. H. Poettmann 271

Mile Six Pool — An Evaluation of Recovery Efficiency, by E. L. Anders, Jr. 279

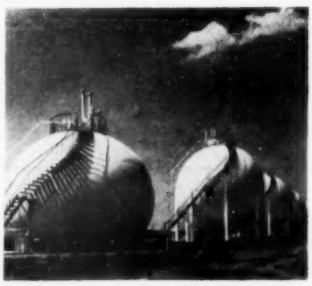
Institute Affairs — Section 2

Employment Notices 1

Petroleum Branch Membership 3

Letter to the Editor 3

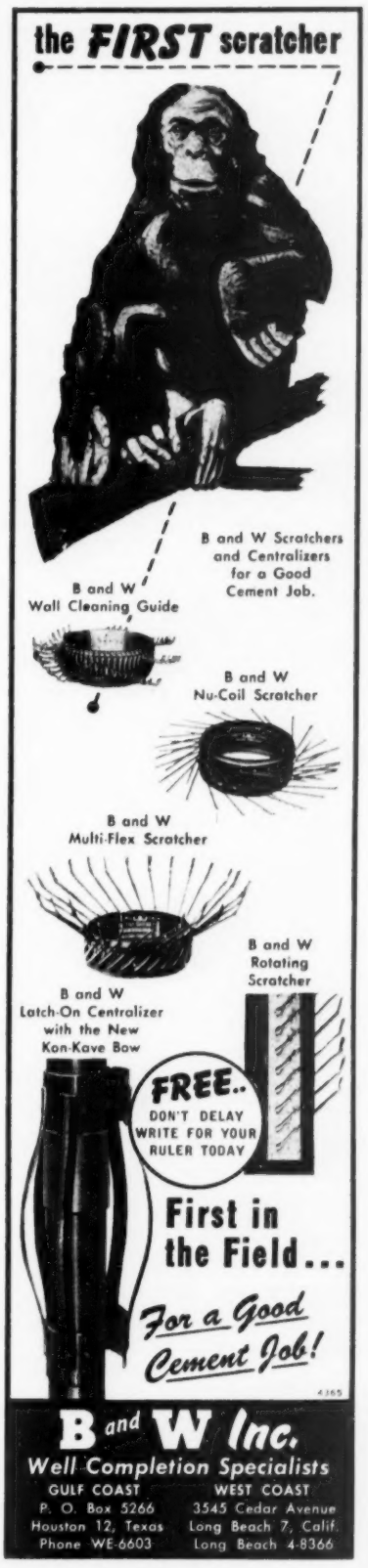
Advertisers' Index 4



— Photo by Doremus

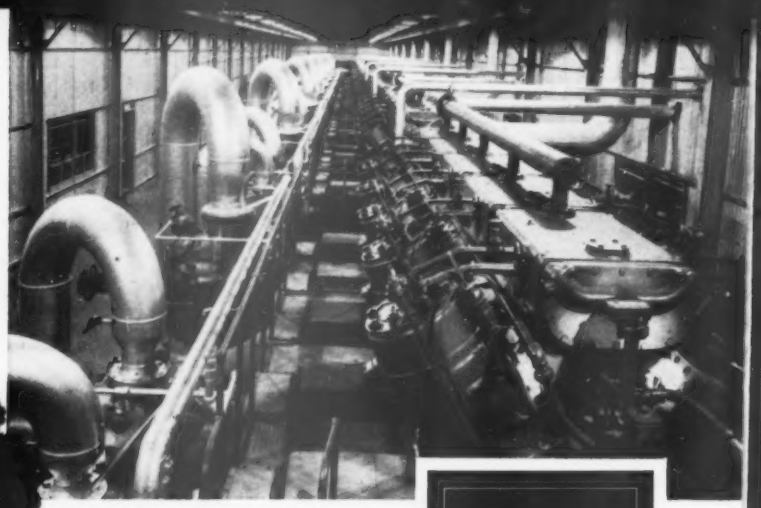
ON THE COVER

Hortonspheres of the new National Petro-Chemicals Corp. plant at Tuscola, Ill., form interesting shape-patterns on this month's cover. Almost 9 million gal. of liquid hydrocarbons can be stored in the tank farm and capacious underground storage caverns. Also produced are synthetic alcohol, ethyl chloride, ammonia, sulfuric acid and ether. The plant cost $50 million.


the FIRST scratcher
B and W Scratchers and Centralizers for a Good Cement Job.
B and W Wall Cleaning Guide
B and W Nu-Coil Scratcher
B and W Multi-Flex Scratcher
B and W Rotating Scratcher
B and W Latch-On Centralizer with the New Kon-Kave Bow
FREE..
DON'T DELAY WRITE FOR YOUR RULER TODAY
First in the Field...
For a Good Cement Job!
B and W Inc.
Well Completion Specialists
GULF COAST
P. O. Box 5266
Houston 12, Texas
Phone WE-6603
WEST COAST
3545 Cedar Avenue
Long Beach 7, Calif.
Long Beach 4-8366

IN THE LATEST SCURRY COUNTY PLANT

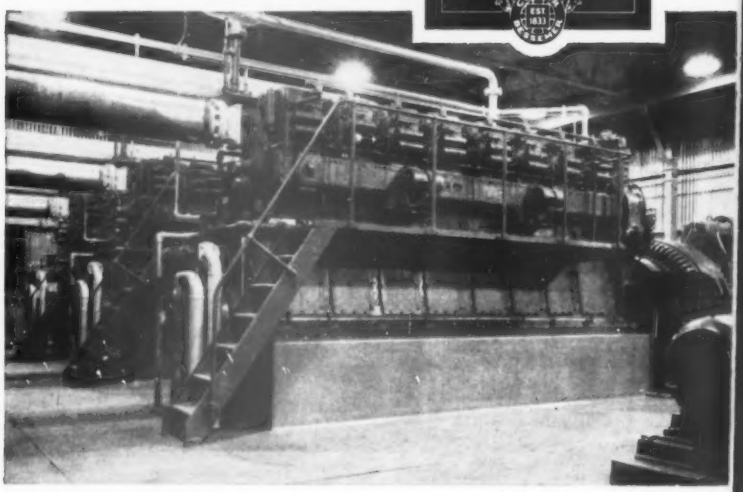
modern Cooper-Bessemers team up for a big 3-way job



This compressor line-up in the Fuller plant now consists of 880 hp GMV-8-TF units and 1100 hp GMV-10-TF units. Each unit is equipped with a high pressure cylinder for injection service.

These Cooper-Bessemer turboflow, spark-ignited four cycle gas engines drive 500 K.W. generators to provide electric power for the operation of all pumps, air compressors and similar equipment.

Another Example of Efficient Power at Lower Cost



GMV's
for processing and injection
JS's
for electric generation

THE Fuller plant in Scurry County, Texas, operated by The Texas Company for the account of the Cogdell Field operator-owners, is one of the newest combination gasoline and pressure maintenance plants to go on stream. Designed and constructed by the O. L. Olsen Company, it has been winning high respect for its latest methods, modern facilities and efficient operation.

Here, as in so many other newsworthy plants, you'll find Cooper-Bessemer units at the heart of the operation. GMV compressors handling process and injection gas — JS gas engines driving 500 K.W. generators.

Check up. You'll find that your power needs, too, can best be met with modern Cooper-Bessemers.

The **Cooper-Bessemer** *Corporation*

MOUNT VERNON, OHIO — GROVE CITY, PENNA.

New York City Washington, D. C. Bradford, Pa. Parkersburg, W. Va.
San Francisco Houston, Dallas, Greggton, Pampa and Odessa, Texas
Seattle, Wash. Shreveport, La. St. Louis, Mo. Los Angeles, Calif.
Caracas, Venezuela Gloucester, Mass. Tulsa, Okla. New Orleans, La.

LUFKIN'S Latest

CONTRIBUTION TO THE ECONOMICAL AND TROUBLE-FREE PRODUCTION OF OIL

400-600
RPM
45-65
HORSEPOWER

the NEW
H-795
TWO CYCLE • TWO CYLINDER
OIL FIELD GAS ENGINE

featuring

- THERMOSYPHON COOLING
- BUILT-IN ELECTRIC OR AIR-GAS STARTER
- PRESSURE LUBRICATION

lufkin

FOUNDRY & MACHINE COMPANY

LUFKIN, TEXAS

Branch sales and service Houston, Dallas, New York, Tulsa, Los Angeles, Seminole, Oklahoma City, Corpus Christi, Odessa, Kilgore, Wichita Falls, Casper, Wyoming, Great Bend, Kansas, Effingham, Illinois, Duncan, Oklahoma, Brookhaven, Mississippi

Lufkin Equipment in CANADA is handled by

THE LUFKIN MACHINE CO., LTD., 14321 108th Avenue, Edmonton, Alberta, Canada.

What's NEW

In Perforating, Logging, and Fishing Tool Services

McCULLOUGH
NEW SERVICES • NEW TOOLS
NEW WAYS OF DOING THINGS

Latest News About New Tools, Techniques and Services

"The security of your entire drilling investment may depend on the reliability of your logging information"

That's why operators everywhere are specifying dependable McCullough Radiation Well Logging utilizing the amazing new Scintillometer. It is the most accurate and reliable logging instrument available to the oil industry. It is a stable instrument, and because of its stability, it is consistently reliable — one or ten trips in the well, you'll always get the same answer.

1. The Scintillometer is very short compared to the length of gnseous type counters. This enables the measurement of formations with a great deal more detail. It will measure and define very thin beds that would be averaged out with the longer counters.

2. The efficiency of the Scintillometer in measuring radiations approaches 100%. Gaseous type counters may have an efficiency in the order of 2% or less.

3. As a result of the short length and high efficiency of the Scintillometer, a much more detailed log can be produced at a faster logging speed than with other methods.

4. The Scintillometer responds only to external excitation and thus can be calibrated on an absolute scale. This scale is in International Units and assures a more accurate quantitative interpretation.

ACCURATE — RELIABLE — CONSISTENT — STABLE

Gamma Ray and Neutron Logs

McCULLOUGH

Radiation Well Logger

with SCINTILLOMETER

5. Because of the extreme stability of our equipment, we are able to duplicate successive runs in the same well with accuracy.

6. Characteristics such as time constant and sensitivity are controlled at the surface. Thus, these variables can be set to provide the operator with as much or as little detail in his log as he desires.

7. The Scintillometer will record the entire range of gamma radiations, or only a certain band within the range can be recorded if desired.

8. It has no instrument, temperature nor discernable cosmic drift and can be used as a valuable reference tool.

9. Simultaneous recording of a collar log simplifies "pinpoint" perforating later.

10. The original record is reproduced as the final log—no retouching nor tracing is necessary.

THE McCULLOUGH RADIATION WELL LOGGER WITH SCINTILLOMETER (GAMMA RAY AND NEUTRON LOGS) IS AVAILABLE IN MOST ACTIVE OIL FIELDS—CALL YOUR McCULLOUGH SERVICE ENGINEER FOR COMPLETE INFORMATION.

PERFORATING, RADIATION LOGGING, AND FISHING TOOL SERVICE—ANYWHERE—ANYTIME.

McCULLOUGH TOOL COMPANY

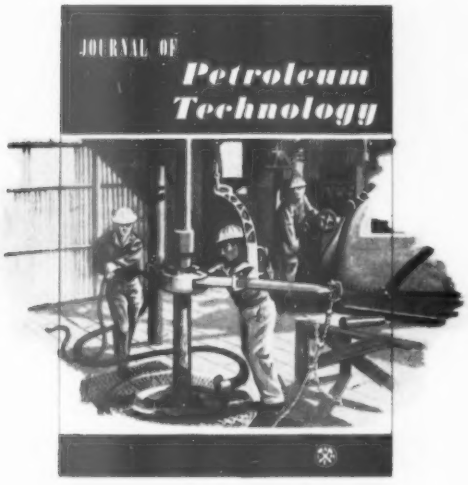
5820 South Alameda Street, Los Angeles 58, California
405 McCarty Street (P. O. Box 2575) • Houston, Texas

CABLE ADDRESS: MACTOOL

EXPORT OFFICE: Los Angeles, California

CANADA: Edmonton, Calgary, Grande Prairie, Alb.; Regina, Saskatchewan
VENEZUELA: United Oilwell Service Co., S.A.; Caracas, Anaco, Maracaibo

SERVICE LOCATIONS: **TEXAS:** Houston, Snyder, Alice, Cisco, Corpus Christi, McAllen, Odessa, Tyler, San Angelo, Victoria, Wichita Falls, Luling, Beaumont, Sherman, Midkiff, El Campo. **OKLAHOMA:** Oklahoma City, Guymon, Healdton, Hominy, Wewoka. **ARKANSAS:** Magnolia. **MISSISSIPPI:** Laurel. **NEW MEXICO:** Hobbs. **KANSAS:** Great Bend. **WYOMING:** Casper. **CALIFORNIA:** Los Angeles, Avenal, Bakersfield, Ventura. **LOUISIANA:** Houma, Lake Charles, New Iberia, Shreveport. **COLORADO:** Sterling. **NORTH DAKOTA:** Williston. **UTAH:** Vernal.



drilling

26 per cent of the members of the Petroleum Branch of the A.I.M.E. influence rotary drilling equipment for their companies, 41.3 per cent are concerned with casing operations, 47 per cent with control equipment, 50.3 per cent with cementing, 67 per cent with logging and core analysis, 58 per cent with acidizing and shooting, 20 per cent with power transmission . . . and so on. *Journal of Petroleum Technology* circulates to more than 5,000 of these men . . . men who either specify or approve 78 per cent of the equipment and services their companies buy. Petroleum technology is their business, and *Petroleum Technology* is the magazine they read.

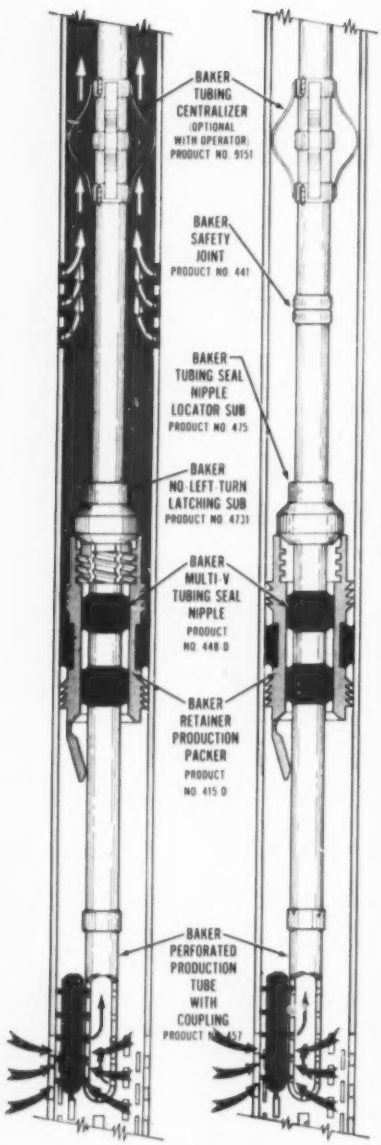
IF YOUR PRODUCT IS TECHNICAL, ADVERTISE IT TO THE TECHNICAL MAN

JOURNAL OF PETROLEUM TECHNOLOGY IS PUBLISHED MONTHLY BY THE PETROLEUM BRANCH, AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS • DALLAS, TEXAS

SINGLE ZONE

production with ONE

BAKER
RETAINER
PRODUCTION PACKER


BAKER TUBING CENTRALIZER (OPTIONAL WITH OPERATOR) PRODUCT NO. 9151
BAKER SAFETY JOINT PRODUCT NO. 441
BAKER TUBING SEAL NIPPLE LOCATOR SUB PRODUCT NO. 475
BAKER NO-LEFT-TURN LATCHING SUB PRODUCT NO. 473J
BAKER MULTI-V TUBING SEAL NIPPLE PRODUCT NO. 448-D
BAKER RETAINER PRODUCTION PACKER PRODUCT NO. 415-D
BAKER PERFORATED PRODUCTION TUBE WITH COUPLING

Typical Dual Zone Hookup

Typical Single Zone Hookup

Do you know that with only ONE Baker Retainer Production Packer you can equip your well for *either* SINGLE ZONE or DUAL ZONE production? And that you can accomplish *any* type of completion for *any* method of production to meet *fixed* or *changing* well conditions?

A single Baker Retainer Production Packer will also outperform many specialized tools when used as a TESTING PACKER – SQUEEZE PACKER – GAS LIFT PACKER – PERMANENT COMPLETION PACKER – WATER FLOOD PACKER – GAS INJECTION PACKER – CORROSION CONTROL PACKER – TUBING ANCHOR – ONE-WAY BRIDGE PLUG – PERMANENT BRIDGE PLUG.

Every production man should be familiar with the many operating advantages of this "Universal Type" Packer, which include . . .

WIRE LINE SETTING – The packer can be set with *wire line speed and accuracy*, using the same set-up just used for perforating. The Baker Packer also can be set on drill pipe or tubing.

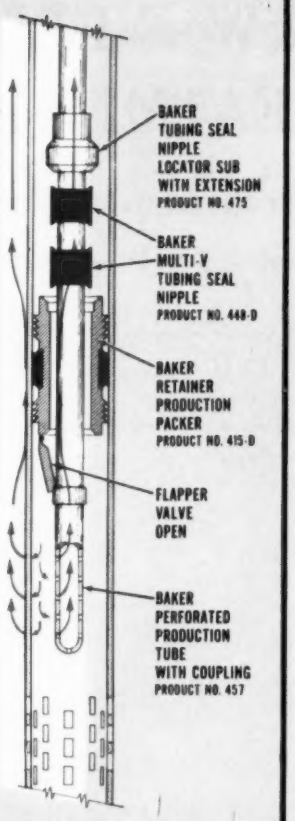
SETTING UNDER HIGH PRESSURE – By using a lubricator, the Baker Retainer Production Packer can be set under high pressure. From the moment it is set, the self-contained, flapper-type, back-pressure valve closes and isolates pressure below the packer.

TUBING STRING IS ALWAYS "FREE" – That valuable string of tubing – whether 1,000 feet or 16,000 feet in length – can be removed by simply picking up the tubing weight.

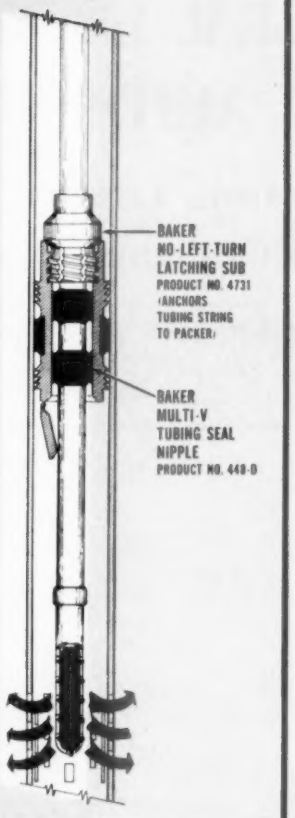
EXCESSIVE "SET-DOWN" WEIGHT OR TENSION NOT REQUIRED – Even when squeezing, formation fracturing, or producing at any depth under pressure, a perfect pack-off is maintained independent of excessive set-down weight, or tension.

HOLDS PRESSURE DIFFERENTIALS FROM ABOVE OR BELOW – Two sets of opposed slips, and a resilient packing confined by lead and metallic sealing rings, effect a permanent pack-off that will hold any pressure differential *either from above or below the packer* that is safe for the well equipment.

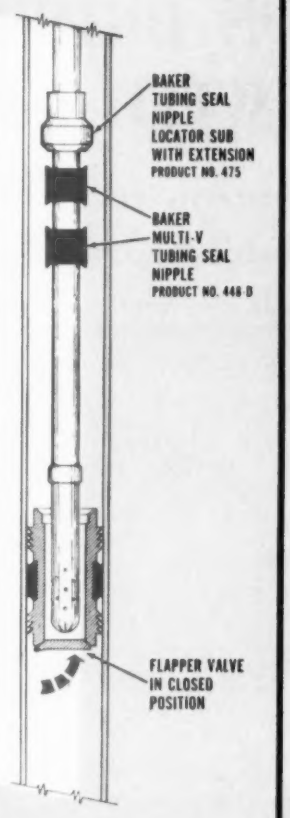
PACKS-OFF AND HOLDS UNDER HIGH BHT – Baker Retainer Production Packers will hold high pressures under conditions of high temperatures. Hundreds of Baker Packers are in successful service in Southwest and Gulf Coast areas where temperatures in excess of 300 degrees are not uncommon.



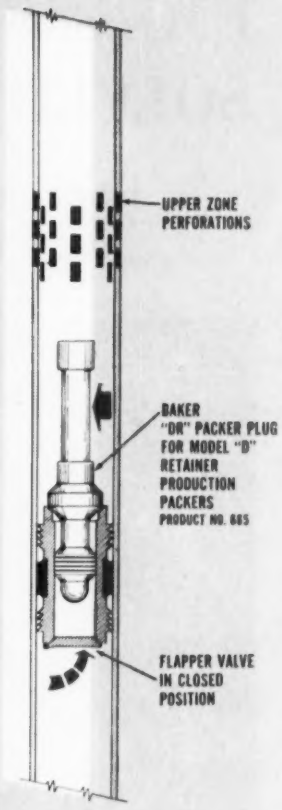
Washing or Circulating Tubing Seal Nipples removed from packer bore. Flapper Valve held open by tubing extending below Tubing Seal Nipples.



Pressuring Below Packer Acid or cement squeeze, formation fracture, gas or water injection. Latch Sub used when squeeze pressures exceed tubing weight.



Isolate Zone Below Packer Tubing String removed, Flapper Valve closed. Isolates pressure differentials (squeeze, productions) from below the packer.



Temporary Bridge Plug For working over zones above packer. DR Plug run in on Baker Retrievable Comerter, and retrieved with overshot. *Permanent Bridge Plug* can be formed with Trip Bob (not illustrated).

RESISTS CORROSION —The cast-iron used in the construction of Baker Packers is far more resistant to corrosion than the casing in which the packer is set, thus making it ideal for permanent installations, or for use in areas plagued with a severe corrosion problem.

EASILY DRILLABLE —The Baker Packer is constructed of drillable cast-iron, and its design supplements the breaking-up action of the bit. Whether it has been in the well for only a few hours, or for ten years, the Baker Packer can be drilled up in minimum time. Expensive and hazardous "milling-out" operations never are required.

IMPORTANT FACTS

Baker Packers are used in a majority of installations where conditions of extreme pressure, temperature, or depth are present. Baker Packers also dominate Dual Zone installations, particularly those involving two-packer, crossed-flow arrangements.

BUT IT IS ALSO TRUE that *more* Baker Packers are used for *simple single zone* completions than for *any other type of completion,* and that *most* Baker Dual Zone installations employ *only one* packer.

Ask any Baker representative, or office, for complete details, as well as your copy of the recent Baker Equipment News dealing with DUAL ZONE COMPLETION PRACTICES. There is no charge, and no obligation, for specific recommendations and completion planning advice available from Baker Technical Advisers. Why not be prepared for your next completion?

BAKER OIL TOOLS, INC.

HOUSTON • LOS ANGELES • NEW YORK

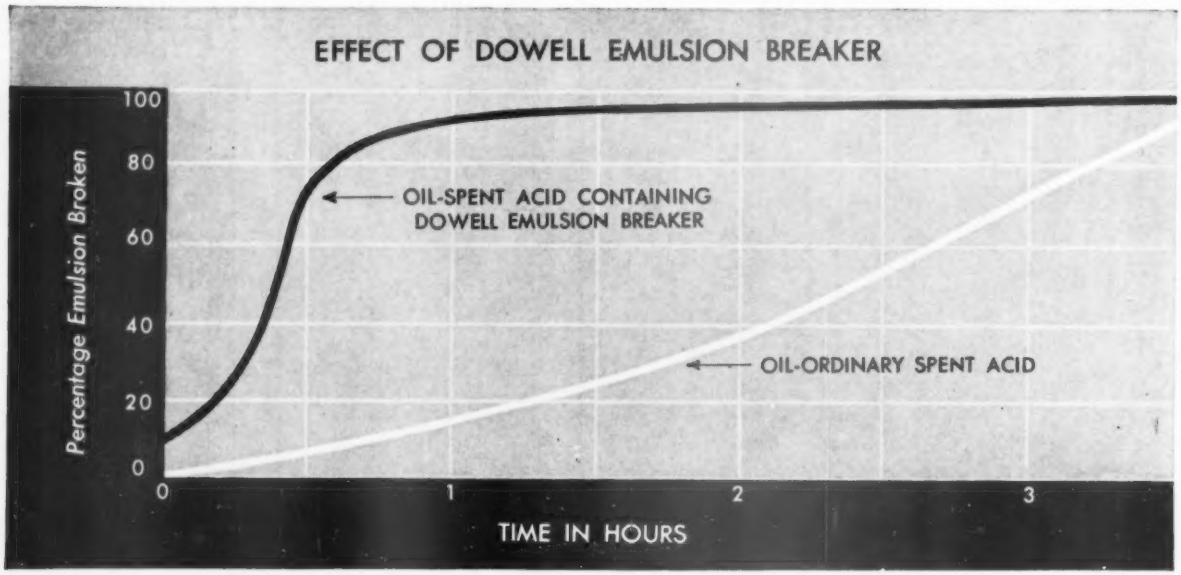
IF YOUR WELL IS WORTH COMPLETING,
IT'S WORTH COMPLETING WELL,
WITH A

BAKER

RETAINER PRODUCTION PACKER

EMULSION PROBLEM IN NEW WELL SOLVED WITH XW ACID TREATMENT

Fast clean-up resulted from DOWELL treatment with inhibited acid plus demulsifying agent



A wildcat well—5123 feet deep, with 77 feet of broken pay in hard, dolomitic lime—was exceptionally difficult to bring into production because of the presence of a stable oil/water emulsion.

The well could be produced only by bailing. Then, the operator contacted Dowell. After a careful laboratory study of the emulsion, Dowell recommended a three-stage treatment using inhibited acid containing surface tension reducing and emulsion breaking agents. The second stage of the treatment resulted in 2 BOPH production, swab and flow. The third and final stage brought a substantial production increase, flowing with no emulsion trouble.

Dowell addition agents have been developed to provide operators with answers to many of the difficult conditions encountered in oil, gas and water wells. These developments are the result of over 21 years of experience in oilfield services using chemicals. Other Dowell additive chemicals are designed to remove mud from producing formations; to speed reaction rate; to increase penetrating ability; to remove "gyp"; to trace fluid movement; to increase acid weight.

For more information on Dowell XW Acid, other addition agents and the many oilfield services and products offered by Dowell, contact the nearest Dowell Office. Or, write directly to Tulsa, Dept. I-15

DOWELL SERVICE

Acidizing • Fracturing • Electric Pilot • Perfojet
Paraffin Solvents • Bulk Inhibited Acid • Jelflake®
Corban® • Chemical Cleaning for Heat Exchange Equipment

DOWELL INCORPORATED • TULSA 1, OKLAHOMA
A Subsidiary of The Dow Chemical Company

"First in Oilfield Acidizing . . . Since 1932"

Look to DOWELL
FOR OIL INDUSTRY CHEMICAL SERVICE

Integrating Well Completion Practices

By H. F. Hopkins

Assistant Division Manager

Halliburton Oil Well Cementing Co.

Houston, Texas

When the problem of just exactly how to initially complete or re-complete an oil or gas well arises, it is impossible to refer to any known formula and obtain an always correct answer. Only in rare cases do individual well characteristics compare too closely within any given field, much less from field to field or area to area. There are far too many unknowns existing within the depths of drilled hole to permit formula solution to be applied to completion practices.

Fortunately, for all concerned, the techniques, processes, materials, etc., now employed and utilized are efficient enough to permit a great industry to thrive and expand, and civilization to benefit from the products of this industry's efforts. Based on the now known improvements in efficiency effected during the 20 years just passed, it is logical to assume that much is yet to be done by way of developing better drilling, surveying, cementing, perforating and treating methods. Any such development would naturally lead to more complete depletion of reservoirs, greater possible rates of production, and, by no means least in importance, more economical production.

It would seem that the ideal goal for the petroleum industry would be to drill wells and complete them in a manner which would accomplish the following:

1. In no way reduce the naturally occurring permeability and porosity of formations which are to be produced.
2. Insure equal or greater protection from vertical migration of formation fluids from one zone to another as is afforded by nature.

It is extremely doubtful that perfection such as outlined above can ever be attained; however, study reveals that great strides have been made in the proper direction.

Experience has taught those concerned to plan the drilling and completion of a contemplated well with due consideration being given to each separate phase. Each successive step is taken with the idea in mind of complementing the steps to follow in the best possible manner. Hole sizes are planned in accordance with intended casing sizes, formation characteristics, etc. Drilling fluids are compounded and adjusted to fit known conditions and to take care of anticipated conditions. The same degree of anticipation and control should be exercised over any steps taken that might, later on in the program, affect the cementing work to be done.

Some of the factors which are now known definitely to affect prime cementing results are as follows:

1. Relation of hole size to size of casing run.
2. Quantity and nature of filter cake developed within hole.
3. Condition of wall of hole as results from type of bit used, unusual washout, angle of drilling and other factors.
4. Relation of weight of cement slurry to weight of drilling fluids being used.
5. Nature of slurry used.
   (a) Gel properties
   (b) Filler materials, etc.
6. Pumping rates developed while cement is being pumped into place.

When consideration is being given to cementing methods the error is often made of treating conductor and surface jobs too lightly. This discussion is not primarily concerned with this level of cementing; however, it should be noted that it is often just as important to cement properly these strings as it is to effect a good cement job on protection or long strings. Failure to do so can cause expensive delays in and prolongation of drilling time, blowouts and other undesired effects.

Giving consideration to the individual steps as they would occur in the drilling of surface hole, logging and/or calipering of open hole, ordering cement to be used, running pipe and cementing pipe in hole, the following thoughts are submitted.

Hole Size

For economic and practical reasons, surface holes should be only enough larger than casing which is to be run to permit easy entry of pipe. Excessive hole diameters tend to make it harder to develop desired flow rates during cementing, harder to centralize pipe, and harder to clean filter cake from the hole.

Depth

It is usually a dangerous practice to drill the hole to a much greater depth than intended casing seat. If this excess hole is left unplugged when casing is run, it may develop into a source of loss of bore fluid, due to weight of cement column and cause failure of cement job. Such failure will particularly affect the all-important bottom phase of the job.

Logging and/or Calipering

Until all facts such as depth, thickness and content of formations through which surface pipe is to be set have been determined for any given area, it is a wise practice to log and caliper surface holes. Such practice permits the operator to anticipate more correctly lost circulation tendencies, observe wash-out characteristics and calculate volume of cement slurry needed. Analysis of formation and caliper logs permits more efficient positioning of centralizers and/or wall cleaners. Such information can aid in choosing the type of formation for the casing seat.

Ordering Cement

Normally, due to low temperature condition and the relatively short time involved, Portland ASTM (Type I) cement can and should be used. It has become popular practice to add from 4 to 14 per cent bentonite (per cent by dry weight), and often other materials such as perlites, pozzolanic materials, etc., to basic cement in order to obtain light weight slurries that minimize lost circulation. Due to low compressive and tensile strengths which result from addition of bentonite to cement slurries, many operators make a practice of running approximately 100 sacks of neat cement as a final phase of the cement job. Such an arrangement permits the major portion of the annulus to be filled with light-weight slurry, yet the lowermost section is protected by the strongest and fastest setting material.

Paper presented at the AIME Study Group at Houston, Tex.

Running Pipe

When casing is being prepared for running in hole, at least the first 90 ft should be equipped with centralizers and wall cleaners. Greater coverage with these two items will further insure good results. If possible, the centralizers should be positioned so that they will finally come to rest opposite a section of hole that is near bit size. Wall cleaners, in accordance with their type, should be so spaced and chosen as to give the greatest possible radial coverage of hole within section applied.

When surface strings are equipped with float valves, consideration should be given to tendencies of pipe to develop pressures higher than formations in the lower section of the hole can withstand. If the piston-like action of casing being run in hole once causes some section of hole seriously to break down, considerable damage may result to the cement job.

Cementing Pipe in Hole

Usually surface holes are drilled with light weight slurries of low viscosity; therefore, comparatively little trouble is to be expected from the co-mingling and gelation of mud and cement at their contact in open hole. If conditions are such that it is suspected that cement contaminated mud may interfere with placement of cement, a quantity of 20 or 30 bbl of water can often be used to minimize this condition. Only under extreme conditions is there any need to fear that this practice will cause any ill-effects such as heaving, etc. In order to prevent lubrication or by-passing of cement into the mud below it during the time cement is still in the pipe, both a bottom and top plug should be run.

During no cementing operation is it more important to consider rate of flow than during cementing of surface strings. Howard and Clark, in their paper of November 9, 1948, entitled "Factors to Be Considered in Obtaining Proper Cementing of Casing," point out that flow properties of a plastic fluid are independent of pipe diameter, and that the flow of a plastic fluid divides itself into three broad flow regions; *viz*, plug, laminar, and tubulent. Their tests indicate that the rate of flow at which the cement slurry displaces the circulatable mud in a well greatly affects the per cent of mud displaced. Cement slurry-displacement rates in the plug-flow region seem to displace approximately 60 per cent of circulatable mud, in the laminar-flow region approximately 90 per cent, and in the turbulent-flow region better than 95 per cent. If we calculate the flow rate in barrels per minute necessary to develop the flow rate in feet per minute corresponding to turbulent flow in a case where $10\frac{3}{4}$-in. casing is set in 15-in. hole, we find that it would be approximately 50 bbl/min. For middle of the region laminar flow, 19 bbl/min are required for same pipe and hole sizes. Certainly the feasibility of developing pumping rates approximately 50 bbl/min during a cementing job is nil; however, rates of 19 bbl/min are well within the capacity of several Gulf Coast rigs and could probably be effected without ill effect to equipment or hole. Laminar-flow would be much more desirable than plug-flow which is more often than not in effect during surface pipe cementing jobs. The likelihood of creating a greater contaminated section on top of the cement column as well as dispersing greater quantities of drilling mud in the cement column is increased; however, due to the very nature of the drilling mud at this stage of the well, it is unlikely that much interference to placement would develop. It would be necessary to exercise precaution and reduce pump speed near the end of the job in order to land the plug safely.

Cementing Protection Strings

The processes and techniques normally employed when cementing intermediate or protection strings are quite similar to those employed in cementing the production string. As a rule, protection strings are set wholly for the purpose of expediting deeper drilling; therefore, the actual success of the cement job is often never known. Protection strings, like surface strings, must withstand the forces and punishment resulting from drilling through and below it. Again, it is highly essential that the bottom joints be as nearly perfectly cemented as is possible. There are many instances were corrosive fluids occur in quantities that demand extensive coverage of pipe by cement in order to protect the pipe. In such cases, the cement can be brought up the annulus to the desired height by use of light weight slurries or multi-stage cementing equipment.

When and if protection strings are planned and run, it is sometimes desirable to place and utilize a multi-stage cement tool to supplement a deliberately shortened surface string. This practice can and may be practically utilized in this type of operation. Centralizers and wall cleaners should be planned on the same basis as long strings if future production is planned through this string and similar to surface strings if production is not planned. Pump rates should be dictated that will, where possible, create turbulent flow during placement of cement.

Cementing Production Strings

Since the cement behind a long string (production string) serves so many different purposes and its efficiency is tested and exposed in so many different ways, much more is done to effect perfection than is usually done for earlier cement jobs. During the stage of running and cementing of production pipe, the operator is faced not only with all the problems of obtaining an efficient job from the standpoint of fill-up, good slurry, total coverage and good bonding, but is also faced with the problem of avoiding any detrimental effects to the possible producing horizons through which he is cementing. This latter problem often precludes the use of some of the materials and/or techniques that may be used on upper strings. Because of increased depths with correspondingly greater formation pressures it becomes increasingly difficult to isolate penetrated formation one from another. Often the shale beds separating two or more fluid bearing sand bodies are extremely thin and permit only a very short zone of protection along the axis of the bore. The occurrence of two or more different fluids within a single sand body becomes more prevalent and creates a more difficult isolation problem. The occurrence of abnormal pressures in certain formations penetrated calls for the use of a drilling fluid whose column weight may exceed the tensile strength of other formations exposed within the bore. Quite often a different situation exists whereby it is possible to drill the hole with relatively light fluids whose weights may be so low that it is impractical to match them with weight of cement slurry to be run, yet greater columnar weight created by cement causes loss of circulation during cementing. Higher differential pressures, accompanied by higher temperatures tend to develop thicker and tougher filter cakes. These same pressures and temperatures encourage the use of drilling fluids that are extensively treated with chemicals that may interfere with proper setting of cement slurries. All of the above mentioned factors, and many more are not listed, face a Gulf Coast operater when cementing a pr.duction string.

In addition to above mentioned hazards, the very nature and content of the prolific producing sands along and adjacent to the Gulf Coast create a secondary problem of major importance. Almost without exception the sands overlying the Wilcox are highly permeable and porous and carry bentonite in some form. In most cases this bentonite occurs not only in form of interbedded lenses or streaks but is found to be interspersed throughout the sand body. Unfortunately, this

bentonite is of a type that will expand when brought into contact with fresh water. The capacity of some of the bentonites encountered by adsorbing and holding fresh water is such that their particle sizes will be increased to the extent that permeability of parent formation is drastically reduced. The water to cause this ill-effect can be introduced into formation from drilling fluids in the form of filtrate or from fluids pumped in with or tangent to cement slurry. Except in the cases where the water lost into formation is either nil or extremely low, it is doubtful that appreciable damage is done by water lost from the cement slurry.

In addition to the damage caused by filtrates it is possible to severely impair the potential productivity of a sand body by forcing great quantities of cement into it while pumping down. This can and does happen to sand bodies that contain numerous lenses of shale, lignite, etc.

In order to obtain best results possible and minimize damage to formations penetrated when preparing to run and cement a production string, the following should be properly considered:

1. Consult the electric log and the caliper log, where possible, and determine location for centralizers and wall cleaners. If a caliper log is not available, assume the hole to be near bit size in sand sections and to be washed out to a greater diameter in the shale sections. Try to position centralizers in sections of hole expected to be near bit size. Place wall cleaners as recommended by the manufacturer.
2. If multi-stage equipment is to be run, place it in the string according to the purpose intended.
3. It has been found to be very beneficial to plan and execute several periods of circulation during running in of casing. Each period of circulation is continued until fluid has been returned from bottom and/or cuttings from well bore cease to return. This practice does much to reduce the final circulating pressure, thereby reducing the hazard of lost circulation.
4. When pipe has been landed and circulation has been established, circulation should be maintained until filter cake and cuttings displaced by lowermost wall cleaners have been returned to the surface. If circulation and returns are normal, cement as soon as assured cuttings have been received from bottom. If pipe is landed, circulation is possible out through the casing shoe and no returns appear at the surface. Two methods of procedure are most common; *viz.* (1) if pumping pressure is normal, proceed with the cement job in the usual manner, or build up content of lost circulation material in drilling mud and try to re-establish circulation before cementing.

   If casing becomes stuck at or near the landing point and circulation is lost, it is often necessary to "nipple up" and go in the hole with a squeeze tool and squeeze cement through the casing shoe. Before this is done, however, an attempt should be made to determine depth at which the pipe is stuck. This latter information will aid in determining where casing should be perforated for cementing of annulus above the section creating restriction in the hole.
5. The choice of the type of cement to be used calls for consideration of depth of casing to be cemented, temperature of the bottom of the section to be cemented, length of time needed to mix and land volume of cement to be run, nature of formations to be covered, and capacity of formations affected by cement column to withstand pressure.

   During the past few years, enough wells have been seemingly successfully cemented with cement slurries that have been modified or blended with various materials such as bentonite, pozzolanic materials, expanded perlites, special dispersing and/or retarding agents, etc., that the user can feel safe in blending a slurry to fit the occasion in the weight range of 12.5 lb/gal. to 18 lb/gal. Though some operators will question the advisability of running slurries whose compressive strengths have been considerably reduced by addition of bentonite, records on wells that have been completed for more than two years seem to verify users' faith in the product. Special combinations of materials named above can be blended to individual needs of any well or any area.
6. Since plugs are now available that can safely be run ahead of cement on prime jobs to prevent contamination of cement with drilling fluids while such fluids are still in the casing and simultaneously wipe inside wall of casing clean, the use of same has become almost universal. The use of a bottom plug can prevent the contamination of the cement which comes to rest around the bottom joint or joints and in the area between guide or float shoe and float collar. It is possible for this zone of contamination to be of major importance.
7. Surface cementing equipment, such as plug containers, should be chosen with the idea in mind of minimizing or eliminating stoppage of fluid travel once circulation has been established ahead of the cement job. When plug-container type cementing heads were originally developed, their main purpose was to eliminate possibility of entrapped air columns occurring between the cement and the top plug. Intelligent analysis of the ill-effects possible from this condition indicates that there is nothing to be feared; however, movement of casing is often impossible after circulation is allowed to stop during the cementing operation. This situation develops in many fields throughout the Gulf Coast Area.
8. Observation of results indicates definitely that better cement jobs are obtained where casing is moved during cementing operation. The type of movement, spudding or rotation, is dependent upon the type of wall cleaning equipment being used or the discretion of the operator if no wall cleaning equipment is present.
9. As was pointed out earlier, once the cement has started out of the bottom of the pipe and up the annulus, far better results will probably be obtained if circulation rates in the region of turbulent flow are developed. Such flow can be developed with typical slow-set cement as follows:

Hole Size	*Pipe Size*	*Flow Rate (Bbl/Min)*
7⅞ in.	5½ in.	8.5
9⅞ in.	7 in.	13.0

   Such flow rates are within the capacity of the majority of the larger rigs running on the Gulf Coast.
10. The practice of leaving any designated amount of pressure on casing after plugs are landed is becoming less common. If floating equipment is holding after plug is down, many operators remove the cementing head immediately after completion of the job.
11. If the well being cemented is a wildcat or if any unusual effects are noticed in connection with returns during cementing, valuable information can be obtained by running a temperature survey to determine the top of the cement column. If further cementing is to be done, it should be accomplished as soon as possible before the mud in the annulus becomes gelled. It is now known that a successful temperature survey can be run much

Continued on Page 4, Section 2

FOREMOST

IN THE

GEOPHYSICAL

FIELD

FOREIGN OPERATIONS

Western

GEOPHYSICAL COMPANY

INTERNATIONAL

CANADIAN OPERATIONS

Western

GEOPHYSICAL COMPANY

OF CANADA, LTD.

DOMESTIC OPERATIONS

Western

GEOPHYSICAL COMPANY OF AMERICA

Henry Salvatori, President

PACIFIC MUTUAL BUILDING, LOS ANGELES 14, CALIFORNIA

SHREVEPORT • MIDLAND • CASPER • PANAMA CITY • CALGARY

UNEXCELLED BAROID FIELD SERVICE has, for years, been based on engineering your drilling fluid — at your rig.

Baroid's engineer is your engineer. His training and experience in drilling fluid problems enable him to make valuable recommendations before the well is spudded in. Fully equipped with Baroid's perfected portable mud testing equipment, he can make "on the spot" mud tests and recommend the best materials and techniques for drilling fluid control.

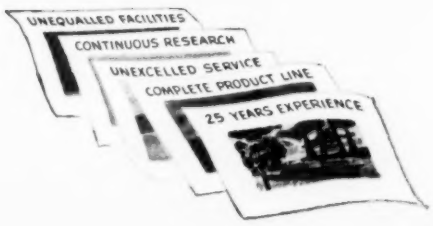
The technical knowledge and skill of Baroid's dependable service and research team, supported by 25 years of field experience and energetic research, is quickly available night and day wherever wells are drilled throughout the United States and Canada.

Five hundred strategically located Baroid distribution points throughout the oil areas keep a complete line of drilling mud products only minutes from your rig.

These are the reasons why the word "Baroid" and the sight of the familiar blue service car are synonymous with the best in drilling mud products and services — for greater drilling safety — better mud control — lower drilling costs.

NOW AS EVER

you can rely on Baroid's



Unexcelled Service

: for faster, more efficient drilling!

Baroid Sales Division — National Lead Company • Houston • Tulsa • Los Angeles ☆ Main Office: P. O. Box 1675, Houston 1, Texas

3959

Working Partnership

Informal as it appears, this "curbstone conference" is deciding the entire future of a major investment. Operator, drilling contractor, and Baroid field service engineer . . . together they are planning the mud program for a new well even before the well is spudded in.

Such conferences are a commonplace sight in today's oil fields where operators and contractors know, from experience, that the recommendations of a Baroid "mud engineer" on drilling fluid control can aid them greatly in making hole faster, more economically, and with a minimum of trouble. Avail yourself of the thorough drilling fluid knowledge and practical experience of *your* Baroid field man.

BF-204

you can rely on **Baroid**

HOUSTON · TULSA · LOS ANGELES

Baroid Sales Division • National Lead Company ☆ Main Office: Houston, Texas • P. O. Box 1675, Houston 1, Texas

Technical Note 192—

AN EXPLANATION OF THE YUSTER EFFECT

BY **P. H. SCOTT** AND **WALTER ROSE**, CONTINENTAL OIL CO., PONCA CITY, OKLA.

Recent papers[1,2] by S. T. Yuster have called attention to the largely ignored concept that there will be a transfer of viscous forces across fluid-fluid interfaces during the flow of immiscible fluid phases through porous media. This leads to the implication that the relative permeability *vs* saturation function, as applied to each of the fluid phases of the system, will in some way be dependent on the viscosities of all the other fluid phases which are contiguous to the flowing fluid of interest. In fact, Yuster has selected and analyzed the properties of a capillary-tube model of the reservoir-prototype flow systems and concludes from his studies that relative permeability values will be very markedly influenced by the viscosity ratio in two-phase systems. On the other hand, relative permeability data have been reported in the literature for more than 20 years; and where these data are consistent at all, they consistently show no dependence on viscosity ratio (cf. chapter 7 of Muskat[3] for a resume of past experimental work). This paradoxical situation has prompted us to re-evaluate Yuster's work.

The major flaw we find has to do with the properties of the model Yuster employed to give qualitative support to his predictions. This model is defective in that important surface area parameters characteristic of the prototype-reservoir flow system have not been propertly scaled. Fig. 1 shows how we believe Yuster's model should be modified to circumvent this difficulty. It depicts the capillary tube of radius R and length L, comprised of two elements in series. The first part of length, L_1, has the nonwetting phase flowing centrally out to a radius distance r, where an interfacial boundary exists with the wetting phase which flows in the concentric annular space of the tube. The second part of length, L-L_1, has the nonwetting phase similarly located but separated from the similarly located wetting phase by a solid-phase boundary (of infinitesimal thickness) instead of by a fluid-fluid boundary. Elementary geometry gives the properties of our model as:

Saturation of the nonwetting phase $= S_N = \left(\frac{r}{R}\right)^2$

Surface area of contact between the nonwetting and wetting phases $= A_i = 2\pi L_1 r$

Surface area of contact between the nonwetting phase and the solid phase $= A_s = 2\pi(L - L_1)r$

Total surface area of contact between the fluid and solid phases affecting the flow of the nonwetting phase $= A_T = 2\pi L_1 R + 2\pi(L - L_1)r$

[1]References given at end of paper. Manuscript received in the Petroleum Branch office Aug. 18, 1953.

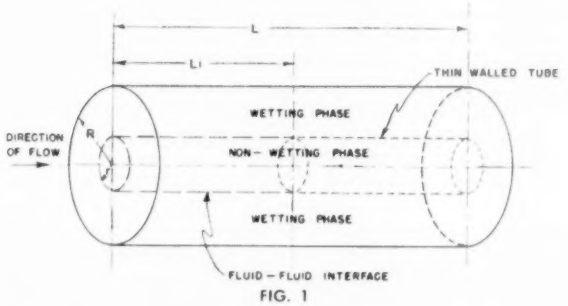


FIG. 1

From these definitions and with the aid of the analytical expressions previously developed by Yuster, we obtain:

$$K_{RN} = \frac{S_N^2\left[2(1-S_N)\frac{\mu_N}{\mu_W} + S_N\right]}{\left(\frac{L_1}{L}\right)S_N + \frac{L-L_1}{L}\left[2(1-S_N)\frac{\mu_N}{\mu_W} + S_N\right]} \quad . \quad (1)$$

Where K_{RN} is the nonwetting phase relative permeability, μ_N/μ_W is the nonwetting phase to wetting phase viscosity ratio, and where:

$$\frac{L_1}{L} = \frac{A_i}{A_s + A_i} \quad \text{and} \quad \frac{L-L_1}{L} = \frac{A_s}{A_s + A_i}$$

To solve Equation 1 and to examine its limits at high and low values of viscosity ratio, it is necessary to scale the model by making reasonable assumptions about the (A_i/A_T) and (A_s/A_T) functions. We have done this by assuming $(A_s/A_T) = S_N^y$ where y is some positive number. This function satisfies the proper limits of:

$(A_s/A_T) = 0$ at $S_N = 0$

and

$(A_s/A_T) = 1$ at $S_N = 1$

and in other respects is in accord with theoretical expectations. Our assumption leads to the condition that:

$$(A_i/A_T) = S_N^{1/2}(1 - S_N^y) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Where the proper limits of $(A_i/A_T) = 0$ hold when S_N is zero or unity

Fig. 2 shows a plot of Equations 1 and 2 for the case where $y = 1$. It is seen that the (A_i/A_T) ratio passes through

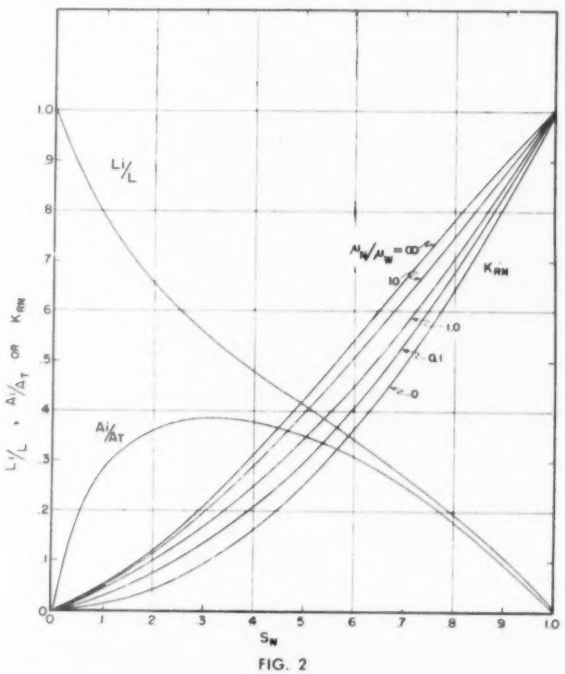


FIG. 2

a maximum of 0.38 at $S_N = 0.33$, which is not an unreasonable generalization of Leverett's theoretical conclusion[4] about the nature of this function. More important to our present purpose, however, is the fact that Fig. 2 gives a much narrower range of dependence of nonwetting fluid relative permeability on viscosity ratio than was obtained by Yuster in the unmodified model; and perhaps this explains why previous experimental work has failed to show the effect.

In any event, while being in general agreement with Yuster that Darcy's law does not exactly describe multiphase flow phenomena, we are unwilling to infer that past experimental work has been grossly in error. In recent years the concept has gained wide acceptance that multiphase fluid flow through porous media takes place with each phase flowing mostly in separate channels. In this type of flow each phase is mainly in contact with solid pore walls, and the liquid interfacial area is thus small. We, therefore, believe that it is necessary to account for the limited amount of fluid-fluid interfacial surface area as has been done in our modified model before positive conclusions can be drawn from the analytic solutions of simplified models. Other work we have done along these lines, which involves the use of a different type of model and which extends the usefulness of Yuster's concept that some of the transfer of viscous forces at fluid-fluid interfaces results in eddy currents, will be published elsewhere. Our consistent finding, however, is that departures from Darcy's law in multiphase fluid flow through porous media are a second-order effect, dependent on the occurrence and distribution of fluid-fluid boundaries, on the viscosity ratio, and on the relative motion of the immiscible fluids at the interfacial boundaries.

REFERENCES

1. Yuster, S. T.: *Proc.* Third World Petroleum Congress (1951), Sec. II, 436.
2. Odeh, A. S., and Yuster, S. T.: "The Effect of Viscosity on Relative Permeability," presented at Annual Meeting, AIME, Los Angeles, Feb., 1953.
3. Muskat, M.: *Physical Principles of Oil Production*, McGraw-Hill, (1951).
4. Leverett, M. C.: "Capillary Behavior in Porous Solids," *Trans.*, AIME, (1941), **142**, 151.

★ ★ ★

Technical Note 206—

THE STEADY-STATE FLOW OF GAS THROUGH GLASS CAPILLARY TUBES

GEORGE C. WALLICK, MAGNOLIA PETROLEUM CO., DALLAS, TEX.

ABSTRACT

This paper describes experimental procedures for the calibration of capillary tubes to be employed as comparison standards in gas flow-rate measurements and considers several types of flow which were observed in the calibration of seven capillaries of varying diameter. It is shown that under certain experimental conditions deviations from Poiseuille flow are observed which may not be attributed to turbulence, and that this flow behavior may be described empirically by introducing the classical kinetic energy correction into the Poiseuille equation.

INTRODUCTION

Techniques have been developed for the measurement of the volume rate of flow of nitrogen through glass capillary tubes as a function both of the differential pressure applied and of the absolute gas pressure. Capillary tubes thus calibrated are frequently used to determine the rate of gas flow through a porous sample in the measurement of slip-corrected permeability. The purpose of this note is to describe the calibration procedure and to discuss some observed deviations from the ideal flow behavior predicted by the Poiseuille equation.

EXPERIMENTAL PROCEDURE

The volume flow rate of nitrogen as a function of the differential pressure was determined experimentally for a series of seven glass capillary tubes of varying diameter. As is shown in Table 1, the capillary radii in the series ranged from 0.004 cm for K1 to 0.07 cm for K7. The capillary tubes were cut from capillary tubing purchased on special order from several manufacturers and the bore radii were determined by microscopic measurement. The gas volume flow rate was measured for each capillary tube at a series of differential pressures in the range from 0 to 3 cm of mercury and at average absolute pressures of 1.0, 2.5, 4.0, and 6.0 atm.

Experimental Procedure for Small Capillaries

A schematic diagram of the apparatus used to calibrate the three smallest capillaries, K1, K2, and K3, is shown in Fig. 1. By means of a standard Ruska Instrument Corp. volumetric pump (equipped with a synchronous motor drive, two stages of gear reduction, and a quick-change lathe gear box), nitrogen was displaced by mercury from a metal cell immersed in a constant-temperature bath. The pump, the line to the cell, and a part of the cell were filled with mercury. As mercury was forced into the cell, it displaced nitrogen which passed through the capillary tube being calibrated and into a large container with a volume of approximately 30 liters. Since the volume of this container was very large compared to the total volume change of the gas resulting from the action of the displacement pump, the absolute pressure of the system was essentially constant throughout any one run. Prior to any determination this pressure could be set at any desired level by means of an auxiliary nitrogen cylinder. The differential pressure across the capillary was measured with a Meriam Red Oil manometer and recorded together with the corresponding pump displacement rate which was equal to the gas flow rate. By repeating this process for a series of different displacement rates at each of the absolute pressures of interest, the data necessary for plotting the calibration curves for capillaries K1, K2, and K3 were obtained. All calibration measurements were made in a constant temperature room to minimize errors due to temperature fluctuations. In each run, the flow was maintained until equilibrium was established.

Experimental Procedures for Large Capillaries

The flow rates through Capillaries K4, K5, K6, and K7 required to obtain the pressure drops desired were larger than could be obtained from available constant displacement pumps, and it was thus necessary to employ an alternative calibration procedure. The arrangement of apparatus used in calibrating these capillaries at an average pressure of one atmosphere is shown in Fig. 2. Each capillary was calibrated by flowing nitrogen through the capillary and recording the

[1]References given at end of paper.

Manuscript received in the Petroleum Branch office Jan. 6, 1953. Paper presented at the AIME Annual Meeting in Los Angeles, Cal., Feb. 14-19, 1953.

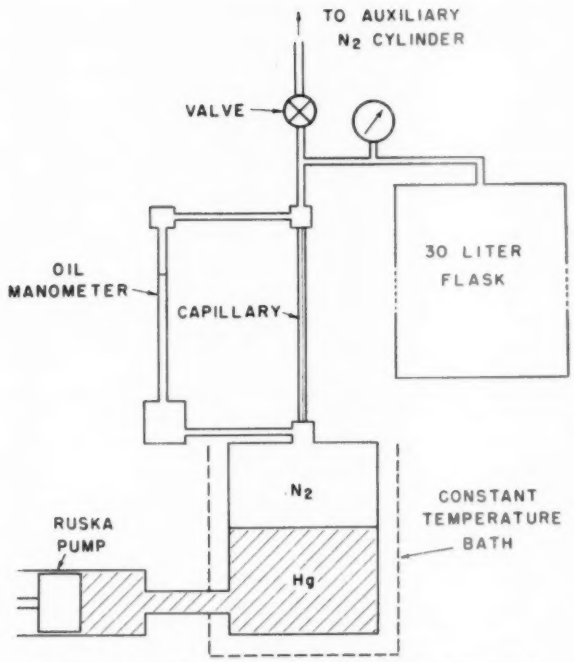


FIG. 1 — CALIBRATION APPARATUS FOR SMALL CAPILLARIES.

differential pressure as a function of the flow rate. The differential pressure was measured with a Meriam Red Oil manometer and the flow rate was determined by collecting the effluent gas over water at constant pressure and recording the increase in volume per unit time after an equilibrium had been established. Appropriate corrections were made for the vapor pressure of water and the water head. The water was saturated with nitrogen prior to each run to avoid error in the volumetric determinations resulting from solution of the effluent gas in the water.

The larger capillaries were then calibrated at the higher absolute pressures, that is, 2.5, 4.0, and 5.0 atmospheres, using the method illustrated in Fig. 3. The capillary to be calibrated was connected in series with a precision needle valve and this, in turn, in series with the capillary of this group having the next largest bore. The gas pressure in the first capillary was then raised to the desired level by means of a nitrogen cylinder and the needle valve was adjusted until equilibrium was reached at the desired average pressure and differential pressure. The pressure at the exit of the comparison capillary was maintained at one atmosphere and the volume flow rate through the capillary was determined from the differential pressure across the comparison capillary and the calibration curve previously determined for the comparison capillary at one atmosphere. The corresponding volume flow rate at the test pressure was then calculated from the ideal gas law. (No appreciable error was introduced by this calculation since nitrogen is known to behave essentially as an ideal gas in the range of pressures used in this investigation.[1])

It must be emphasized that this calibration procedure requires that a true equilibrium be established before the data are recorded, and considerable care and patience must be exercised to insure that this condition exists. The method is feasible only if the flow rates are sufficiently high, for only under these conditions may an equilibrium condition be recognized with certainty. An attempt to verify the method by recalibrating capillary K3 using K4 as a comparison standard proved to be unsuccessful as a result of the very small flow rates involved and the consequent indeterminateness of the equilibrium condition.

Since capillary K7 was the largest in the series it was necessary to modify the above described procedure still further by removing the comparison capillary and by collecting the effluent gas over water at a pressure of 1 atm. The flow rate at the test pressure was then calculated from the observed increase in trapped volume per unit time and the ideal gas law.

EXPERIMENTAL RESULTS

The Poiseuille equation for the laminar flow of an ideal gas through a circular conduit may be written in the form:

$$\mu Q = \frac{\pi r^4}{8L} \Delta p \quad \ldots \ldots \ldots \ldots \ldots \quad (1)$$

where Q is the volume rate of flow at the average pressure $\overline{p} = (p_1 + p_2)/2$, and $\Delta p = p_1 - p_2$ is the differential pressure (pressure drop across the capillary).* It is seen from Equation 1 that a plot of μQ vs Δp should be a straight line and that, if the viscosity is independent of pressure, this line should be the same for all average pressures. The viscosity of nitrogen is known to increase by less than one per cent as the pressure is increased from 1 to 6 atm at room temperature and is thus a constant within the limits of accuracy of the calibration measurements.[2]

This straight line relationship was found to hold for the three smallest capillaries, K1, K2, and K3 with radii of 0.0040 cm, 0.0055 cm, and 0.0180 cm, respectively. In each case the same straight line was obtained for each of the four average pressures investigated. For the remaining capil-

*See Nomenclature list at end of paper.

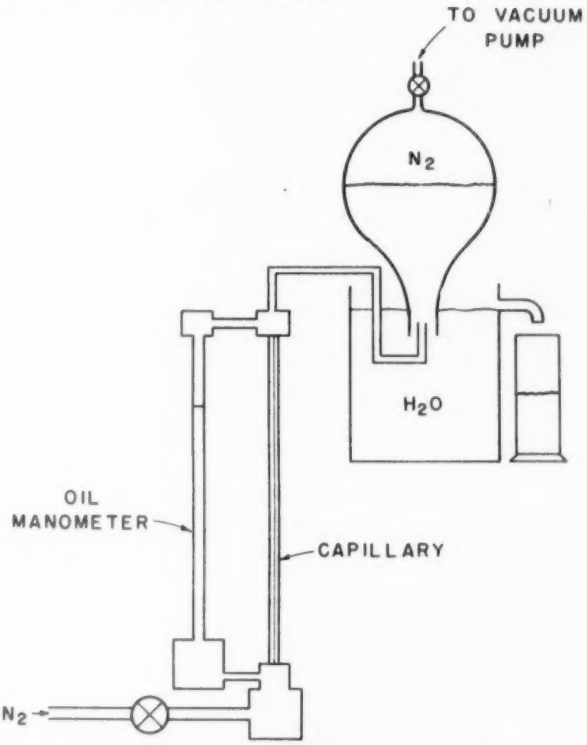


FIG. 2 — APPARATUS FOR THE CALIBRATION OF LARGE CAPILLARIES AT 1 ATM.

laries of larger radii, the volume flow rate at a given differential pressure was found to be less than that predicted by the Poiseuille equation and to be a function of the absolute average pressure, decreasing with increasing pressure. Typical experimental curves for capillary K5 ($r = 0.0254$ cm) are shown in Fig. 4 and Fig. 5.

Similar curves were obtained for capillary K4 ($r = 0.0153$ cm) but in this case, both the amount of deviation from a straight line and the change in flow rate with a change in average pressure were less than for K5. The effect was appreciable only for differential pressures greater than 1.6 cm of mercury.

Deviations from the ideal straight line calibration were even greater for the two largest capillary tubes K6 and K7 with radii of 0.0386 and 0.0700 cm, respectively. For average pressures greater than 1 atm, the calibration curves for these capillaries were observed to flatten out appreciably as the differential pressure was increased.

INTERPRETATION OF EXPERIMENTAL RESULTS

The Poiseuille equation for the flow of an ideal gas through a circular tube is valid only under certain idealized conditions. A number of complicating factors may give rise to deviations from the straight line relationship between μQ and $\triangle p$ predicted by this equation.

Gas Slip and Turbulence

If there is an effective slipping of the gas along the surface of the capillary tube, the resultant flow rate will be greater for a given value of $\triangle p$ than that predicted by the Poiseuille equation — an effect opposite to that observed experimentally. For the flow conditions considered in this note, the gas slip correction would be always less than 1 per cent.

If the flow velocity through the capillary is sufficiently high, the flow may no longer be laminar and additional energy will be required to maintain a constant flow rate. Such a flow is described as turbulent and usually obtains for values of Reynolds number greater than 2,000. As a result of turbulence, the observed flow rate would be less than that predicted from Equation 1 — the type of deviation observed in the calibration of capillaries K4 through K7. The Reynolds numbers were calculated for each capillary from the observed flow rates at 1 and 4 atm corresponding to the maximum differential pressure of 3 cm of mercury. The results of these calculations are given in Table 1.

It is evident from these results that the 1-atm flow through capillaries K1 to K6 is a viscous flow for differential pressures as large as 3 cm of mercury. The 1-atm flow through K7 is either turbulent for $\triangle p = 3$ cm or is in a transition between viscous and turbulent flow. At 4 atm average pressure, the flow through capillaries K1 to K5 is viscous while the flow through capillaries K6 and K7 is turbulent. The flow through capillaries K1 to K5 is still viscous for average pressures as high as 6 atm with a maximum Reynolds number of 1,500. Thus the deviations from ideal flow behavior observed for capillaries K4 and K5 may not be attributed to turbulence. Similar deviations have been observed by Calhoun and Yuster[3] who indicate that the non-ideal flow probably could be explained on the basis of kinetic energy effects.

Table 1 — Physical Dimensions of Glass Capillary Tubes Investigated and Approximate Reynolds Numbers for $\triangle p = 3$ cm of Hg

Capillary No.	Radius (cm)	Length (cm)	Absolute Pressure 1 Atm Velocity (cm/sec)	N_{Re}	Absolute Pressure 4 Atm Velocity (cm/sec)	N_{Re}
K1	0.0040	27.1	2.8×10^1	1.5	28	6
K2	0.0055	13.8	6.6×10^1	5	66	20
K3	0.0108	23.3	1.2×10^2	17	1.2×10^2	68
K4	0.0153	16.5	4.2×10^2	84	4.1×10^2	315
K5	0.0254	18.5	9.3×10^2	300	8.5×10^2	1080
K6	0.0381	13.0	2.4×10^3	1100	1.64×10^3	3150
K7	0.0700	18.0	2.5×10^3	2000	1.2×10^3	4230

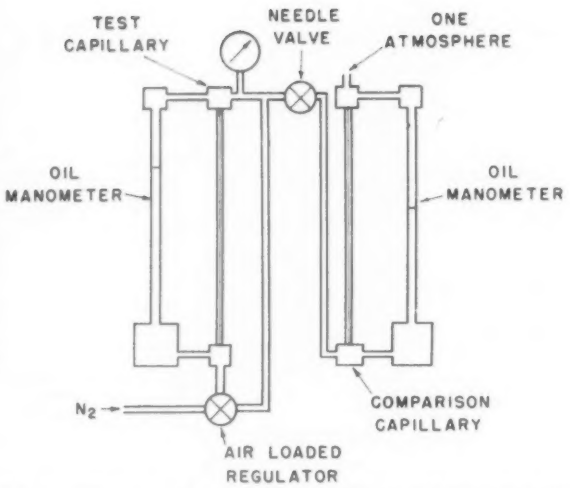


FIG. 3 — APPARATUS FOR THE CALIBRATION OF LARGE CAPILLARIES AT PRESSURES GREATER THAN 1 ATM.

The Kinetic Energy Effect

As the gas enters the small capillary from a larger conduit it must be accelerated in order to maintain the same mass rate of flow through both the capillary and the connecting tubing, and hence must gain in kinetic energy. This additional energy must come from the total energy supplied to the system by maintaining a constant differential pressure across the capillary tube. If this additional energy requirement is taken into account, one obtains an idealized flow equation of the form

$$\mu Q = \frac{\pi r^4}{8L} \triangle p - m \frac{\rho Q^2}{8\pi L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

In this equation, the quantity m is a constant characterizing the capillary tube under consideration. Bingham[4] indicates that experimental values for m of from 0.8 to 1.9 have been observed and while it is probable that the value for m should be the same for all tubes with perfectly cylindrical bores, the value would be very sensitive to slight irregularities in the bore. Moreover, if a value for m is determined from experimental data without taking end effects into account, the resultant value will be influenced by these effects and will not be the same for all capillary tubes.

The viscosity-flow rate product μQ given by Equation 2 is less than that predicted by the Poiseuille equation and the magnitude of this difference will increase with increasing flow rates and/or with increased average pressure. Since the flow characteristics predicted by Equation 2 were qualitatively similar to those observed experimentally for capillaries K4 and K5, calculations were made to determine whether or not the experimental data could be empirically represented by an equation of this form with reasonable values of r and m.

Since the observed deviations were greater for capillary K5 than for capillary K4, the experimental data for K5 were selected for the initial calculations. By substituting experimental values for Q and $\triangle p$ at 1 and 6 atm into Equation 2

Table 2 — A Comparison of Calculated and Experimental Flow Rates Through Capillary K4 for an Average Pressure of 4.0 Atm

Δp (cm Hg)	μQ (cp cu cm/sec)		Per Cent Deviation
	Calculated	Experimental	
1.6	0.00289	0.00288	0.35
1.8	0.00324	0.00324	0.00
2.0	0.003595	0.00360	0.17
2.2	0.003945	0.00394	0.13
2.4	0.00429	0.00431	0.47
2.6	0.00464	0.00467	0.64
2.8	0.00498	0.00503	1.00
3.0	0.005327	0.005375	.91

it was found that $m = 1.6 \pm 0.2$ and that $r = 0.02533 \pm 0.00002$ cm. This calculated value for the radius compares very favorably with that of 0.0254 cm determined by microscopic measurement. Substituting the values of r and m thus obtained into Equation 2, the empirical fit was verified by recalculating values of μQ for representative points on the 1- and 6-atm curves. The agreement between the experimental curves and the calculated points is shown in Fig. 4. For values of $\Delta p \geq 1.0$ cm of mercury, the difference between the observed and calculated flow rates was less than 1 per cent of the observed value.

Using Equation 2 with empirical values for m and r determined from the experimental data at 1 and 6 atm, flow rates were then calculated for representative values of Δp at average absolute pressures of 2.5 and 4.0 atm. The good agreement between the calculated and experimental values is shown in Fig. 5. For $\Delta p \geq 1.0$ cm of mercury the difference between the observed and calculated flow rates was again less than 1 per cent.

A similar series of calculations was carried out for capillary K4. Since the change in flow rate with pressure was less for this capillary, the calculations were based upon the experimental flow rates for $\Delta p \geq 1.6$ cm of mercury. From the curves for 1 and 6 atm it was determined that $m = 2.1 \pm 0.5$ and that $r = 0.01553 \pm 0.00002$ cm as compared to a value for $r = 0.0153$ determined microscopically. Using these values for r and m, flow rates were calculated for an intermediate average pressure of 4.0 atm. A comparison of the calculated flow rates thus obtained with the corresponding experimental values is given in Table 2. The differences between the theoretical and measured flow rates are seen to be 1.0 per cent or less.

On the basis of these results it is evident that Equation 2 is of the correct functional form to represent the flow behavior for capillaries K4 and K5. The calculated values for the kinetic energy constant m of 1.6 ± 0.2 and 2.1 ± 0.5 lie essentially within the range of experimental values previously reported. The relatively large uncertainty in the calculated average m values is not reflected in the calculated flow rates, since these flow rates are insensitive to small changes in m. For example, the calculated flow rate was found to change by less than one per cent when the corresponding kinetic energy constant was changed by 12 per cent.

ACKNOWLEDGMENTS

Acknowledgment is made to the management of the Field Research Laboratories, Magnolia Petroleum Co., for permission to publish the results of this investigation. The author wishes to express his appreciation to E. R. Parish, who performed the experimental work described in this paper.

NOMENCLATURE

L = Capillary length (cm)
m = Kinetic energy constant
N_{Re} = Reynolds number

Continued on Page 4, Section 2

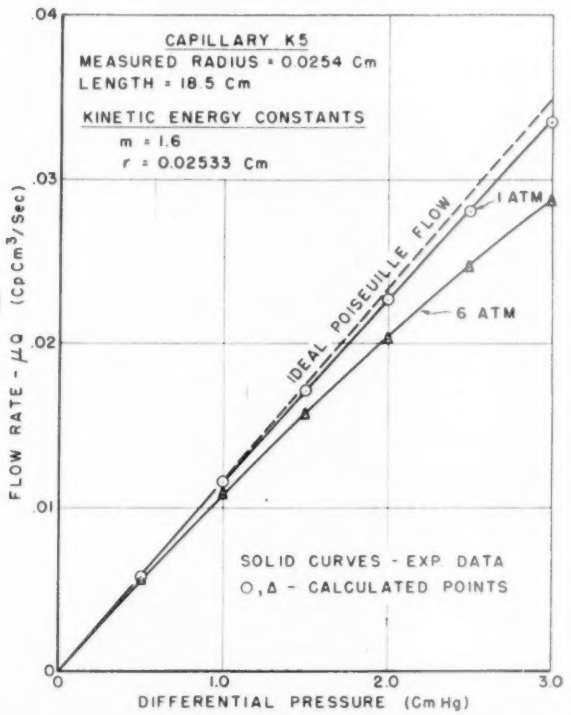


FIG. 4 — EXPERIMENTAL CALIBRATION CURVES AT 1 AND 6 ATM FOR CAPILLARY K5.

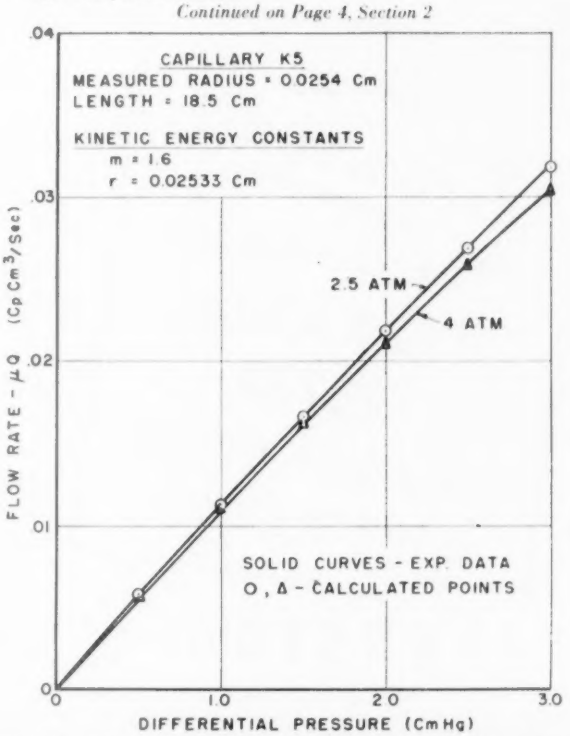


FIG. 5 — EXPERIMENTAL AND CALCULATED CALIBRATION CURVES AT INTERMEDIATE PRESSURES FOR CAPILLARY K5.

NEW JOHNSTON
"HYDRAULIC TESTER"

Eases Pressure Change on Drill Stem Tests

SUDDEN PRESSURE RELEASE-SHOCK TO FORMATION

CONTROLLED PRESSURE RELEASE-NO SHOCK TO FORMATION

AS NEW AS *Tomorrow!*

The new Johnston HYDRAULIC TESTER is compact, rugged and positive

ELIMINATES

SHOCK to formation, pipe and instruments by slowly releasing the pressure below packer; NO INSTANTANEOUS DROP IN PRESSURE; opening is by stages requiring three to six minutes.

LESSENS

Plugging, damage to wall of the hole; requires less water cushion.

GIVES

Smoother, more positive interpretation of productivity in the test zone.

OPERATION

To open, apply drill pipe weight; to close, remove weight by picking up drill pipe.

JOHNSTON TESTERS, INC.

POST OFFICE BOX 165 **HOUSTON, TEXAS**

EXPORT DIVISION: 3035 Andrita St., Los Angeles 65, California

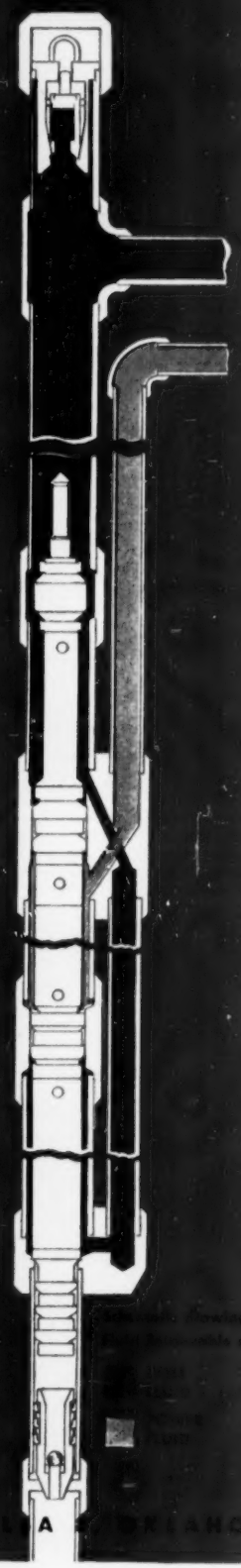
SERVICE BRANCHES IN ALL ACTIVE AREAS

There's a Johnston Service Representative Near You

FORMATION AND CASING TESTING

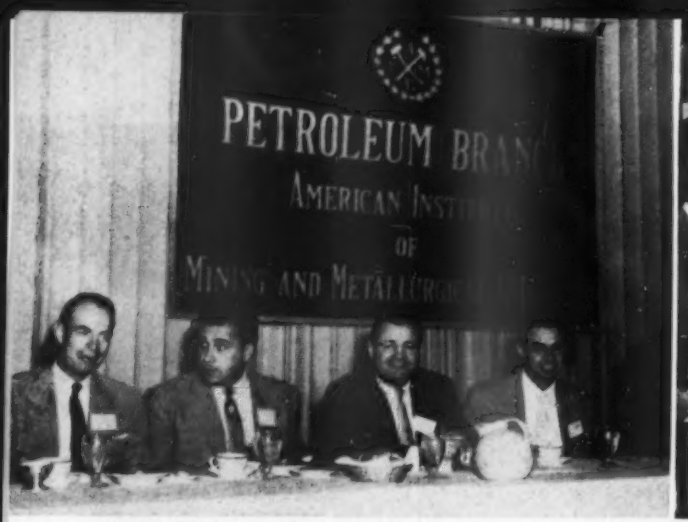
high lift at low operating cost

BJ Hydralift



BJ Hydralift

Byron Jackson Co.



At the Welcoming Luncheon head table are, l to r, Ruford Madera, Hotel Committee chairman; Raul Bethancourt, Arrangements Committee chairman; John H. Murrell, General Chairman; and Claude R. Hocott, Branch Chairman.

At right is the Petroleum Branch exhibit which offered literature on membership and publications available to AIME members.

At the West Coast Regional Meeting, above, are C. C. Liedholm, Program chairman; J. Shannon Baker, Pacific Petroleum Chapter sec.-treas.; and H. M. Stanier, Luncheon chairman. Below, Morton T. Higgs of Lane-Wells receives first prize ribbon from F. L. Wadsworth for "best exhibit" at Los Angeles.

Record Attendance Set

A record attendance of 1,764 AIME members and other petroleum engineers and geologists gathered in Dallas last month for the 1953 Fall Meeting of the AIME Petroleum Branch. Two weeks earlier, in Los Angeles, another 385 engineers attended the AIME West Coast Regional Meeting to push registration for the two meetings past the 2,100 mark.

The Fall Meeting in Dallas, held Oct. 18-21, was the largest such meeting of record held by the Petroleum Branch. All technical sessions and events were attended to near capacity in most cases. Concurrent sessions were held in the Adolphus and Baker hotels.

Out of the meeting came more than 40 technical and economic papers. An indication of the interest generated in the meeting became evident on the first day when H. N. Mallon, president of Dresser Industries, addressed an overflow audience at the Welcoming Luncheon. Mallon was introduced by John H. Murrell of DeGolyer and MacNaughton, general chairman of the meeting.

The Dallas Local Section was host to the meeting. The officers of the various working committees included E. R. Brownscombe, local section chairman; John Wisenbaker, entertainment chairman; R. J. Bradley, finance chairman; R. J. Bethancourt, arrangements chairman; Kenneth Robbins, registration chairman; Brad Mills, publicity chairman; and

Below, John R. McMillan, Petroleum Branch chairman elect, Mrs. McMillan and Mrs. Joe B. Alford at the banquet and dance.

At left, ladies sign the guest book at the milk punch and breakfast held in the Engineers Club of Dallas. At right, Buford Penn, Branch Membership Committee chairman, holds up banner presented to the South Plains Section for leading in the 1953 membership drive on Aug. 31. The final winning section on Dec. 31 will be presented a projector.

at Branch Fall Meeting

Ruford Madera, hotels chairman. Other officers of the Dallas Section are R. T. Bright, vice-chairman, and Tom Morton, secretary-treasurer.

The technical papers were arranged by the Petroleum Branch Technology Committee. This committee is made up of William H. Justice, chairman; Preston E. Chaney, vice-chairman for drilling technology; Don L. Harlan, vice-chairman for production technology; W. F. Speaker, vice-chairman for natural gas technology; and C. C. Liedholm, vice-chairman for California.

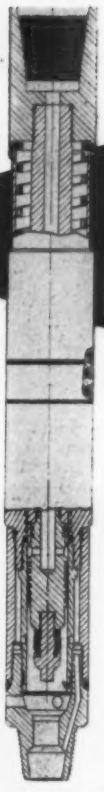
The economics papers were arranged by Douglas Ball, chairman, and Kenneth E. Hill, vice-chairman.

The West Coast Regional Meeting, Oct. 1-2, was held in the Ambassador Hotel in Los Angeles. Morton T. Higgs was general chairman. Pacific Petroleum Chapter officers, from the host section, include F. L. Wadsworth, chairman; J. Shannon Baker, secretary-treasurer; H. M. Stanier, luncheon chairman; W. E. Woodruff, exhibits chairman; C. C. Liedholm, program chairman; and W. R. Wardner, Jr., arrangements chairman.

The West Coast meeting produced three technical sessions and a directional drilling forum. Highlights of the Los Angeles meeting were the Petroleum Chapter luncheon, the Southern California Section luncheon and the annual banquet and dance.

Above, a portion of the 1,764 members and non-members who registered for the meeting collect their badges. Pre-registration of some 350 lightened the work at the meeting considerably. Below, H. N. Mallon, president of Dresser Industries, addresses the Welcoming Luncheon attended by more than 700.

Below, are Mrs. Ben H. Caudle, Eugene R. Brownscombe, Dallas Section chairman, and Mrs. Brownscombe at the banquet.



16,000 FEET

DON'T FAZE HALLIBURTON'S NEW HYDRO-SPRING TESTER

Nothing has stopped this testing tool, not even the super-deep holes. To date, Hydro-Spring has performed perfectly in most every oil field, under all conditions, at depths from 700′ to 16,500′—and right on the first run every time!

Think how much this could save you in trouble, time, and money. You won't be the first who found it out, thousands more have made the swing to Halliburton's Hydro-Spring, so don't be the last to set the old way aside.

Several important features account for Hydro-Spring's success:

1. Opens easily by slacking off weight of drill pipe.
2. Positive indication at surface when tool opens.
3. Packer expands for definite time before tester opens.
4. Combination tool requires fewer assemblies.
5. Locked open by-pass aids in easy, rapid descent of string and helps eliminate formation and packer damage.
6. Initial Hydrostatic mud weight easily read.

Ask around, you're sure to find an operator handy who has run a Hydro-Spring test. And he'll gladly tell you what it's done for him. Then call your nearby Halliburton representative who'll be on the walk with his string made up before you come out of the hole. Halliburton Oil Well Cementing Company, Duncan, Oklahoma.

Hydro-Spring Tester – Patent Applied For

HALLIBURTON

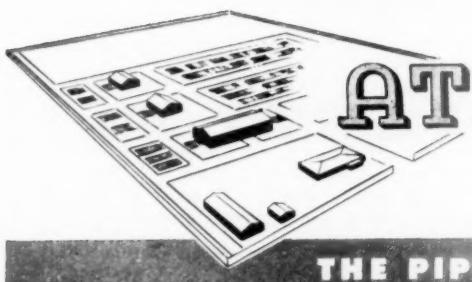
"YEARS AHEAD IN DRILL STEM TESTING"

45 Acres of the South's Finest Pipe Finishing Facilities Devoted to "API" Specifications

Aerial View Houston Plant

Ten skilled inspectors check every operation. Each has memorized the API Manual pertaining to his duties. Gauges are regularly calibrated. We are proud to show visitors through our plant. Call us when you are in Houston.

"The South's Most Modern Plant for Finishing Steel Tubular Goods"



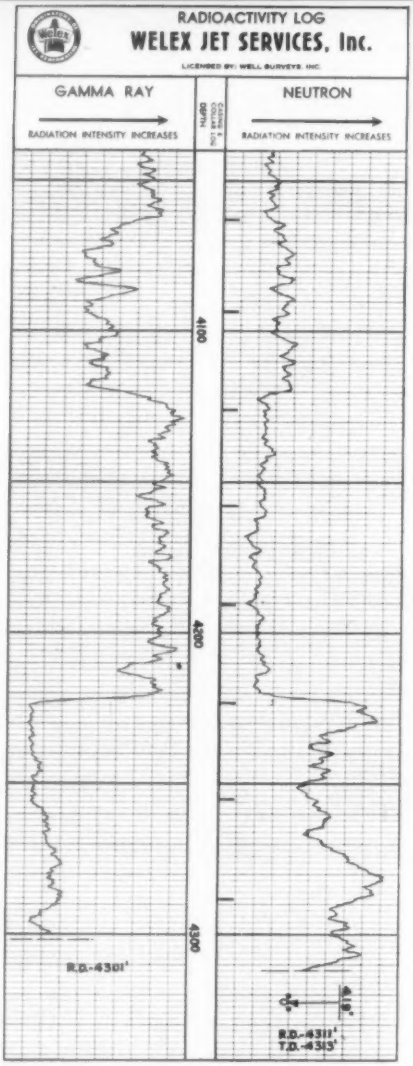
ATLAS PIPE INC.

HOUSTON PLANT: 7707 Wallisville Road
MAIN OFFICE: 511 City National Bank Bldg., Phone: BL 6658 - CE 7316
CORPUS CHRISTI PLANT: P. O. Box 2369, Hwy. 44, Phone: 4-6371

THE PIPE TO BUY IS A. P. I.

Welex RADIOACTIVITY WELL LOGGING . . .

RESULTS YOU CAN RELY ON



A PROCESS THAT IS PROVED

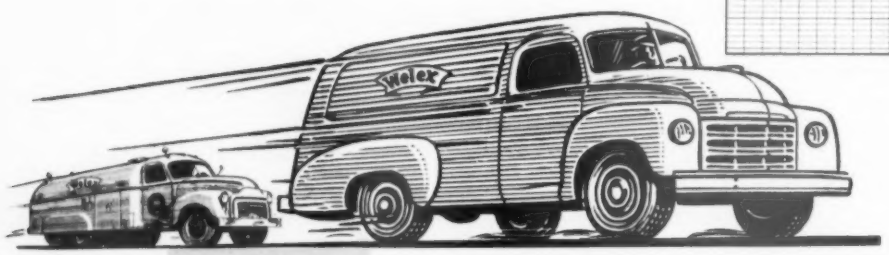
LICENSED BY WSI. Welex Jet Services logs your well by the most advanced radioactivity logging system known to the industry . . . the process perfected by Well Surveys, Inc., of Tulsa, Oklahoma, and proved by successful application throughout the world. Welex field crews, seasoned by years of leadership in jet perforating, are thoroughly trained in the application of this proved process. Welex logging gives you the Gamma Ray and Neutron curves singly or in combination, depending on the problem to be solved.

EQUIPMENT THAT IS IMPROVED

WELEX MODERN EQUIPMENT provides the high degree of precision, sensitivity, and reliability that is essential for maximum value from your radioactivity well surveys. Hoist units, depth measuring equipment, and instrument trucks are the newest and best in the business. Being new in the field of radioactivity well logging, Welex is not burdened with equipment that may be approaching the end of its useful life.

FOR THE LATEST AND BEST

SAFEGUARD YOUR DRILLING INVESTMENT by using logging and perforating processes that are proved effective. *Results* cost less, when you specify the best. Call your nearest Welex Field Station for prompt service day or night.



ORIGINATORS OF Welex JET PERFORATING

Welex JET SERVICES INC.

GENERAL OFFICES: 1400 E. Berry, Fort Worth, Texas

FIELD STATIONS: ABILENE • ARDMORE • BEAUMONT • CORPUS CHRISTI
FALFURRIAS • HOBBS • HOUSTON • ODESSA • PAMPA • •PAULS VALLEY
SAN ANGELO • SHAWNEE • STILLWATER • VICTORIA • WICHITA FALLS

Employment Notices

The JOURNAL will post notices of men and jobs available. Companies and AIME members are invited to use this space, for which there is no charge. Except as noted below, address replies to: Code (appropriate number), JOURNAL OF PETROLEUM TECHNOLOGY, 800 Fidelity Union Bldg., Dallas 1. Show return address on envelope. These replies will be forwarded unopened and no fees are involved.

Replies to positions coded Y9255 and Y9259 below should be addressed to: Engineering Societies Personnel Service, 8 West 40th St., New York 18, N. Y. The ESPS, on whose behalf these notices are published here, collects a fee from applicants actually placed.

PERSONNEL

♦Petroleum engineer, 33, married, BS in petroleum engineering Texas A & M. 9½ years' production, drilling, gas, and geological experience. Presently employed. Desire position with responsibility and opportunity for advancement. Code 203.

♦Petroleum engineer, 30, BS in petroleum engineering University of Houston 1953. Roughneck, roustabout, pumping, and gas plant experience before and since graduation. Desires position with gas or independent oil company. Code 204.

POSITIONS

♦ Petroleum refining technologist, 35-50, with degree in chemical engineering or chemistry, with minimum of five years with petroleum refining company in technological research or development work. Will direct research and development on new refining or chemical processes which the company would license to refiners and chemical companies. Sales contacts with technical people in oil refining companies. Salary, $7,200 a year and up. Location, New York, N. Y. Y9255.

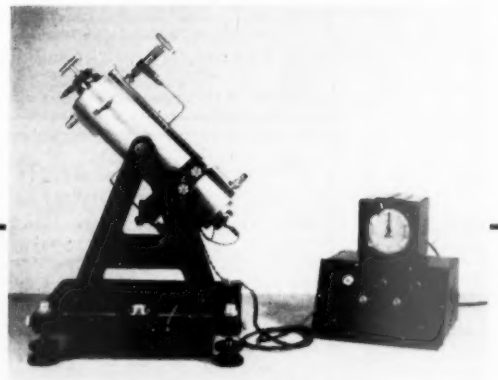
♦Petroleum engineer or geologist with two or three years' experience in Louisiana Gulf Coast. Duties will entail preparation and maintenance of detailed structure and isopach maps of South Louisiana fields and evaluations necessary in field studies. Work located in New Orleans with reliable and financially strong concern. Reply giving age, experience in detail, and salary desired. Inquiries will be kept strictly confidential. Our employees know of this ad. Code 554.

♦Geological engineer and reservoir engineer, each 1-5 years' experience. Reserves and evaluation work for established gas transmission company located in Houston. Some Gulf Coast experience required. Reply stating experience, desired salary, and approximate availability data. Code 555.

CORRECTION

The article by Ralph E. Davis which appeared on page 67 of the September issue of the JOURNAL OF PETROLEUM TECHNOLOGY bore the title, "Three Decades in the Natural Gas Industry," when received by this Journal. The article was published under the title "Gas Technology — Its Growth and Development." Since this latter does not accurately reflect the content of the article, it is regretted that the change in title was made.

Also, on Page 18, Section 1, of the September issue, in the article, "Twenty Years of Oil Well Cementing," by William D. Owsley, the amount of 276,000 tons appearing on line 12 of the first paragraph under the subhead "Bulk Handling," should read 1,220,700 tons.



High Pressure Viscosimeter

INSTRUMENTS for the Oil Industry

Ruska Instrument Corporation specializes in the development and manufacture of scientific instruments for the oil and mining industries.

- Reservoir Engineering
- Pressure Measurement
- Volumetric Pumps
- Core Analysis

Ask for New, Complete 1953 CATALOG

Ruska Instrument Corporation

4607 MONTROSE BLVD. HOUSTON 6, TEXAS

Always UP TO THE MINUTE and DOWN TO THE FOOT!

Yes sir! Geolograph gives you the information you need—at the time it is of the most value to you: *while the well is drilling!*

GEOLOGRAPH

MECHANICAL WELL LOGGING SERVICE

P.O. Box 1291 • Oklahoma City 1, Okla.

Farmington, New Mex. • Liberal, Kan. • Oklahoma City, Okla. • Bakersfield, Cal. Abilene, Houston, Odessa, Lubbock and Wichita Falls, Tex. • Shreveport, and Baton Rouge, La. • Casper, Wyo. • Glendive, Mont. • Sterling, Colo. • Calgary, and Edmonton, Alberta, Canada • Regina, Saskatchewan, Canada

PROFESSIONAL SERVICES

This space available only to AIME members.

AMSTUTZ AND YATES, INC.
Petroleum Engineers and Geologists
Estimates of Oil and Gas Reserves
Property Valuations, Reservoir Analyses
Geologic Investigations
406 KFH BLDG., WICHITA 2, KANS.

E. A. WAHLSTROM BURTON ATKINSON
PETROLEUM CONSULTANTS
Engineering - Geology
MIDLAND, TEXAS
130 Central Building Phone 4-8037

ROBERT M. BEATTY
Consulting Geologist
Esperson Building Houston 2, Texas

BERGER AND PISHNY
Consulting Geologists and Engineers
901 Commercial Standard Bldg.
Fort Worth 2, Texas
Walter R. Berger Chas. H. Pishny

W. RUSSELL BIRDWELL
Consulting Petroleum Engineer
PHONE 6-6601 BOX 1348
Frontier Oil & Gas Bldg.
McALLEN, TEXAS

BRADLEY, OLIVER AND ASSOCIATES
PETROLEUM CONSULTANTS
Geology, Engineering and Management

Robert J. Bradley	R. Wayne Russell
Mac D. Oliver	H. Eugene Wright
Virgil B. Harris	Bernard J. Esunas
Otis T. Griffin	Walter A. Tynes
W. Ray Staples	Kenneth C. English

903 Employers Insurance Building
Dallas, Texas RAndolph-2241

JOHN G. CAMPBELL
Analytical and Petroleum Chemists
Podbielniak and Charcoal Analyses
Waters - Oil Field Brines
Field Sampling
PHONE: 4-3071 CORPUS CHRISTI, TEXAS

CHEMICAL & GEOLOGICAL LABORATORIES
Consultants - Investigations - Evaluations
James G. Crawford.....Chemical Engineer
H. E. Summerford.....Petroleum Geologist
F. Raymond Wheeler.....Petroleum Engineer
P. O. BOX 279 CASPER, WYOMING

CRUTCHFIELD AND PRUETT
CONSULTING PETROLEUM ENGINEERS
Wilson Tower
CORPUS CHRISTI, TEXAS
John W. Crutchfield *Horton T. Pruett*

DENTON-SPENCER COMPANY, LTD.
PETROLEUM ENGINEERS AND GEOLOGISTS
Barron Building Calgary, Alberta

EARLOUGHER ENGINEERING
Petroleum Consultants - Core Analyses
Specializing in Secondary Recovery
Investigations - Appraisals - Operations
3316 East 21st St.
TULSA 5, OKLAHOMA
Phone: 9-6345

EASTON & SACRE
Consulting Petroleum Engineers
1660 Oak Street
BAKERSFIELD, CALIFORNIA
Phone 2-3934

FITTING & JONES
Engineering and Geological Consultants
Ralph U. Fitting, Jr.
J. R. Jones
T. W. Hassell
Petroleum *Natural Gas*
233 S. Big Spring St. Box 1637
Phone 4-4451 Midland, Texas

ROBERT D. FITTING
Petroleum Consultant
Engineering and Geology
MIDLAND, TEXAS
202 West Building Phone: 4-4922

MICHEL T. HALBOUTY
CONSULTING GEOLOGIST
AND PETROLEUM ENGINEER
Shell Building
Houston 2, Texas Phone PR-6376

R. G. HAMILTON
Electric Log Analyses
Log Analysis Conferences
Distributor Arps-Hamilton Loganalyzer
HAMILTON WELL LOG CONSULTANTS
Wright Bldg. Ph. 3-7055; 7-1825 Tulsa

JAMES A. LEWIS ENGINEERING, INC.
Petroleum Reservoir Analysts
Dallas, Texas Evansville, Indiana
Robinson, Illinois
Owensboro, Kentucky Winchester, Kentucky

B. ORCHARD LISLE
Petroleum Technologist — Research Analyst
SPECIALIZING IN MIDDLE EAST OIL
260 Majestic Bldg. FOrtune 0165
FORT WORTH 2, TEXAS

MARTIN, WILLIAMS & JUDSON
PETROLEUM CONSULTANTS
Engineering - Geology - Management
131 Central Bldg. Phone 2-5216
MIDLAND, TEXAS
William H. Martin R. Ken Williams
Edward H. Judson

WAYNE L. McCANN
Petroleum Engineering and Geology
SHREVEPORT, LOUISIANA
Slattery Building Phone: 2-8023

M. M. MONTGOMERY
CONSULTING PETROLEUM ENGINEER
Valuations, Drilling, Well Completions, Production, Workovers, Property Management
Hapip Bldg. Williston,
3-4642 North Dakota

OILFIELD RESEARCH
Core Analysis — Evaluation
Development of Water Flood Projects
Operation of Water Flood Projects
EVANSVILLE, INDIANA
1907 Division Street
PHONES: 6-5591 (Night, 6-4882 or 6-0608)

H. T. OLSEN
PETROLEUM CONSULTANT
Engineering and Unitization
914 Fidelity Union Life Building
Dallas, Texas RAndolph 3746

PETROLEUM CONSULTANTS
Engineering and Geology

E. O. Bennett	James O. Lewis
D. G. Hawthorn	M. D. Hodges
1552 Esperson Building	Houston 2, Texas

KELLER & PETERSON
Petroleum Consultants
Reserve Estimates *Reservoir Analysis*
Petroleum and Geological Engineering
902 W. T. WAGGONER BLDG.
FORT WORTH, TEXAS
Phone: FOrtune 4340
W. O. Keller L. F. Peterson

ERNEST K. PARKS
CONSULTING PETROLEUM ENGINEER
Planning, Direction and Examination of Oilfield Operations, Estimates of Oil and Gas Reserves, Oil Property Valuation
151 N. CANYON VIEW, LOS ANGELES 49, CALIF.
Telephone: Arizona 34832

Rates Upon Request

HARRY H. POWER
PETROLEUM AND VALUATION ENGINEER
Box 1542 University Station
Austin, Texas

E. E. REHN
Consulting Petroleum Geologist
Oil Exploration
Wood Building, 624 Locust Street
EVANSVILLE, INDIANA

SOL SMITH
CONSULTING ENGINEER
PETROLEUM AND NATURAL GAS
Reserves Deliverability
Oil and Gas Proration
913 BROWN BUILDING
AUSTIN, TEXAS PHONE: 8?498

WM. H. SPICE, JR.
Consulting Geologist
2101-03 Alamo National Building
SAN ANTONIO 5, TEXAS

TRAFFORD & ASSOCIATES
Geological, Petroleum Engineering and Management Consultants

E. Trafford		Phones
R. Pot	Wales Hotel Bldg.	61212
P. Klaui	10th Floor	61224
	Calgary, Alberta	63132

Proposed for Membership, Petroleum Branch

Total AIME membership on Aug. 31, 1953, was 19,281; in addition 1,747 Student Associates were enrolled.

PETROLEUM BRANCH ADMISSIONS COMMITTEE

J. H. Sullivan, Chairman; Thomas S. Bacon, Vice-Chairman; A. E. Caraway, Frank C. Kelton, Thomas E. Morton, and F. C. Prutzman.

INSTITUTE ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; Philip D. Wilson, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gensamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, G. W. Lufjen, E. A. Prentis, Sidney Rolle, J. T. Sherman, F. T. Sisco, and R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

ARKANSAS

Smackover — Rushing, John Doss (J)

CALIFORNIA

Beverly Hills — Teitsworth, Robert Allan (J)
La Habra — Perrine, Richard L. (J)
Los Angeles — Clark, Robert Wellington (A); Zublin, C. William (J).
Whittier — Cook, Phillip Granville (C/S, A-M); McNamara, John Edward (J).

ILLINOIS

Carmi — Dailey, John L., Jr. (M).

INDIANA

Evansville — Lavens, John R., Jr. (M).

KANSAS

Great Bend — Boone, Kenneth Johnston (J).
Hugoton — Pyeatte, Claude Preston (M).
Liberal — McDaniel, Robert Eugene (R, C/S, S-J).
Russell — McLaughlin, James Francis (R, C/S, S-J).

LOUISIANA

Lafayette — Records, Louis Russell (M).
Lake Charles — Gaye, Frederick LaFayette (M).
New Orleans — Ilfrey, William T. (M); Laflin, William Leon (M); Tillotson, T. Carrol (M); Wait, Harold V. (M).

MISSOURI

Kansas City — Reese, John Paul (M).

MONTANA

Billings — Dickson, Robert Leonard (A); Lowe, Howard R. (C/S, J-M).

NEW MEXICO

Jal — Haight, Jack Neathery (J).

OKLAHOMA

Bartlesville — Beach, Charles Levi (J); Edinger, Donald B. (M).
Duncan — Jones, Kenneth Eugene (J).
Oklahoma City — McCormick, Robert Louis (M).
Pauls Valley — Atchley, George Wesley (J); Deem, Doy C. (J).
Tulsa — Bickel, Chester Alvin (A); Gore, George Louis (J); Purdum, John Francis (M).
Velma — Brown, Charles Arnold (R, C/S, S-J).

PENNSYLVANIA

Pittsburgh — Convers, Frederick Lloyd (C/S, J-M); Hamilton, Jack Raybun (J).

TEXAS

Bellaire — McNeely, Branch McKissick, Jr. (J); Weiss, Walter John (M); Welch, William Thomas (R, C/S, S-M).
Big Spring — Ellis, Charles Francis (R, J).
Borger — Scarth, Robert Wayne (J).
Brownfield — Underriner, Charles Francis, Jr. (J).
Corpus Christi — Prejean, Joseph S. (J).
Dallas — Boren, Kenneth Locke (J); Byers, John C. (M); Christensen, Milton Paul (J); Daffin, Douglas Edward (M); Douglas, Norvel (M); Dutton, C. Granville Orr (M); Edwards, Stacy Wright (M); Ellis, Howard Edison, Jr. (J); English, Kenneth C. (J); Flagg, Harry Lawrence (J); Garwood, Turner Gerald (M); Gould, Ben Donnell (R, C/S, S-J); Harrison, Alton Andrew (J); Horte, Vernon Lyle (J); Kern, Charles Perrin (J); Olson, Elmer Arthur, Jr. (R, C/S, J-M); Schramm, Harry B. (M); Sheffield, Hugh Donald (J); Stover, Jerry S. (A); Taylor, Donald Franklin, Jr. (M); Taylor, Robert William (J).
Fort Worth — Brown, George Reynolds (M); Geffen, Sam E. (M); Lougee, Earle S. (M); McCloskey, Leo Edward (M); Owen, Harrold Dean (J); Smith, William Dale (J).
Gladewater — Williams, James A., Jr. (M).
Greggton — Neely, Robert Ernest (J).
Hawkins — Kelley, Arthur L. (J).
Houston — Bartran, David Samuel (M); Dublin, James Roland, III (R, C/S, J-M); Franklin, Robert K. (M); Longley, Arvel J. (J); Miller, Leland Homer (J); Moody, Robert Austin (M); Priest, Gerald Gordon (J); Rainey, David Hornsby (J); Singletary, Frank (J).
Irving — Douglas, Alson Howard (R, C/S, S-A).
Kilgore — Bradbury, Robert Milton (M); Metcalfe, Albert Galatin (J).
Longview — Brown, Norman Fraser (M).
Midland — Dedman, Harry Lee (R, C/S, S-J); Fry, Bill Hugh (J); Montgomery, Stuart (M); Myers, Jack Pershing (M); Neill, George Hardin (J); Nicolais, Anthony Louis, (R, C/S, S-J); Schreiber, William Thomas (J).
Odessa — Bishop, Bryan Oliver (J); McLean, Thurman Oliver (M); Mills, Western Hale (M).
Snyder — Weyel, Elmo Groeber (R, C/S, S-M).
Sweeny — Hargis, Jesse W., Jr. (J); Southerland, William Dudley (M).
Tyler — Calvert, John Griffin (R, M); Waid, William Oscar (M).
Wichita Falls — Cunningham, Benjamin Amos, III (R, J); Maki, Ernest Benhart (R, C/S, S-J).
Yorktown — Fish, Howard E. (M); Ramsey, Cleveland Theodore, Jr. (M).

WYOMING

Casper — Banister, John A., Jr. (M).

BOLIVIA

Camiri — Velasco, Miguel Tejada (R, C/S, S-J).

CANADA

Calgary — Murray, Alexander Scovil (M); Spalding, James Gregory (J).
Dewinton — Wright, Walter Gordon (J).
Redwater — Lineham, James Graham (M).

PERU

Talara — Barbieri, Joseph Francis, Jr. (J).

VENEZUELA

Caracas — McCord, David Robert (M); Pratt, Samuel Fletcher, Jr. (J).
Jusepin — Prieto-Willson, Francisco (C/S, S-J).

Letter to the Editor

Editor's Note: The following letter from Mr. Frank M. Bosco was received by the president of AIME as an open letter to the Institute, and was forwarded to this office for publication.

RE: Affiliated Societies. This question seems to resolve itself into one of service or controlling power, to the detriment of membership numbers and members' benefits.

Others, including myself, have long recognized the AIME as the highest cost of the professional engineering societies, and except for publications, it appears inferior to the AICE, AIEE, and AAPG, rendering a lesser service in relation to cost, and putting out generally an inferior magazine from the standpoint of quality of comprehensive technical articles.

The Engineering Societies Employment Service, except Petroleum Branch, is too complicated in its demand for information and too unwieldy in operation to render a real service to members.

I therefore believe it behooves us members to consider the increased service which we can render, and be less concerned with expansion into areas already well served. Unless, perhaps, as AAPG does, have area societies, and list also other related societies and their officers and dates and places of meetings. These would include the Denver, Billings, Tulsa, Oklahoma City, and Casper Petroleum Engineers, and the Rocky Mountain, Mid-Continent, West Texas-New Mexico, Four Corners, South Texas, Texas-Louisiana Gulf, etc., for area societies of AIME.

A prime service would be providing "distinguished lecturers" for the meetings of related societies, paying their expenses and scheduling their "tour."

Please note I have the heart to criticize, yet it is constructive for I am and have been a member since 1932. I think we should return our dues costs to the low figure, through cutting out overhead, and through donations from the members who "happen to be blessed with prosperity by the Lord."

Very sincerely,
Frank N. Bosco
Consulting Petroleum
Exploration Engr.

Steady State Flow of Gas

Continued from Page 23, Section 1

p_1 = Pressure at high pressure end of capillary (dynes/sq cm)
p_2 = Pressure at low pressure end of capillary (dynes/sq cm)
$\bar{p}$ = Average pressure = $(p_1 + p_2)/2$ (dynes/sq cm unless otherwise indicated)
$\triangle p$ = Differential pressure = $p_1 - p_2$ (dynes/sq cm unless otherwise indicated)
Q = Volume flow rate at pressure $\bar{p}$ (cu cm/sec)
r = Capillary bore radius (cm)
μ = Viscosity (poise, unless otherwise indicated)
ρ = Average density (grams/cu cm)

REFERENCES

1. Hougen, O. A. and Watson, K. M.: "Chemical Process Principles," Combined Edition, John Wiley and Sons, New York, (1947) 485.
2. *Ibid.* 870-873.
3. Calhoun, J. C. and Yuster, S. T.: "A Study of the Flow of Homogeneous Fluids Through Ideal Porous Media," *Drill. and Prod. Prac.*, API, (1946), 335.
4. Bingham, E. C.: "Fluidity and Plasticity," McGraw-Hill Book Co., New York, (1922) 17-21, 49-51. ★ ★ ★

Well Completion Practices

Continued from Page 15, Section 1

sooner than previously thought. Laboratory investigation, backed by field results, shows that different brands of oil well (slow-set) cements develop their individual periods of maximum heat of hydration. It has also been proved that there is very little time elapse between the temperature peak reached in the setting cement and the temperature peak reached by the mud in the casing opposite cement. The period at which maximum heat of hydration occurs in any brand of cement is influenced by native temperature of the well being cemented and possibly by the amount of pressure applied to cement and by water-cement ratio used in mixing. The following data are submitted as a guide for determining the earliest logical hour for temperature surveying brands of cement noted.

Brand of Cement	*Temp.*	*Pressure*	*Time*
Lone Star Common	120°F	1750 psi	2 hr, 40 min
	140°F	2700 psi	1 hr, 50 min
(Water-cement ratio	170°F	4000 psi	1 hr, 40 min
0.46)	200°F	5500 psi	1 hr, 30 min
Longhorn Slo-Set	140°F	2700 psi	6 hr, 0 min
	170°F	4000 psi	7 hr, 0 min
(water-cement ratio	200°F	5500 psi	7 hr, 30 min
0.40)			
Trinity Inferno	140°F	2700 psi	6 hr, 0 min
(water-cement ratio	170°F	4000 psi	7 hr, 30 min
0.40)	200°F	5500 psi	10 hr, 0 min
Univ. Atlas Unaflo	140°F	2700 psi	6 hr, 0 min
(water-cement ratio	170°F	4000 psi	6 hr, 30 min
0.40)	200°F	5500 psi	8 hr, 30 min
Lone Star Starcor	140°F	2700 psi	4 hr, 0 min
	170°F	4000 psi	2 hr, 45 min
	200°F	5500 psi	3 hr, 0 min

The temperature evolved, at least in part, seems to linger in mud inside casing in zone opposite cement for an indefinite period. There are surveys on record that were made 36 hours after plug was landed that definitely show the position of cement in hole. ★ ★ ★

Advertisers' Index

American Iron & Machine Works . . . . . *
Lowe Runkle Co., Oklahoma City, Okla.
Atlas Pipe, Inc. . . . . Sec. 1 — 29
Wallace Davis & Co., Houston
Baash-Ross Tool Co. . . . . Sec. 1 — 2
Dozier-Eastman Co., Los Angeles, Cal.
Baker Oil Tools, Inc. . . . . Sec. 1 — 10, 11
Theo. M. Martin Co., Los Angeles, Cal.
Baroid Sales Division . . . . . Sec. 1 — 17, 18
Brennan Advertising, Houston, Tex.
B & W, Inc. . . . . Sec. 1 — 5
Brennan Advertising ,Houston, Tex.
Byron Jackson Co. . . . . Sec. 1 — 25
Ruthrauff & Ryan, Los Angeles, Cal.
Clark Bros. Co., Inc. . . . . *
Harold Warner Co., Buffalo, N. Y.
Cooper-Bessemer Corp. . . . . Sec. 2 — 6
Griswold-Eshleman Co., Cleveland, Ohio
Core Laboratories, Inc. . . . . Sec. 1 — 4
Duvall Williams, Dallas, Tex.
Dowell Incorporated . . . . . Sec. 1 — 12
MacManus, John & Adams, Inc., Detroit, Mich.
Dresser Industries, Inc. . . . . *
Laughlin, Wilson, Baxter & Persons, Dallas, Tex.
Eastman Oil Well Survey Co. . . . . *
Ted Workman Advertising, Dallas, Tex.
Geograph Co. . . . . Sec. 2 — 1
Lowe Runkle Co., Oklahoma City, Okla.
Geological Well Service Co. . . . . *
Matlock-Wilson Advertising, Dallas, Tex.
Halliburton Oil Well Cementing Co. . . . Sec. 1 — 1, 28
Hill & Christopher, Los Angeles, Cal.
Harbison-Fisher Mfg. Co. . . . . *
Dan Goodrich, Dallas, Tex.
Hughes Tool Co. . . . . Third Cover
Foote, Cone & Belding, Houston, Tex.
Hycalog Co. . . . . *
Glenn Mason Advertising, Shreveport, La.
Johnston Testers, Inc. . . . . Sec. 1 — 24
Wallace Davis & Co., Houston, Tex.
Journal of Petroleum Technology . . . . . Sec. 1 — 9
Dan Goodrich, Dallas
Kobe, Inc. . . . . *
The McCarty Co., Los Angeles, Cal.
Kimray, Inc. . . . . *
Brandenburg Advertising, Tulsa, Okla.
Lane-Wells Co. . . . . Fourth Cover
Darwin H. Clark Co., Los Angeles, Cal.
Lufkin Foundry & Machine Co. . . . . Sec. 1 — 7
A. E. Cudlipp, Lufkin, Tex.
Magnet Cove Barium Corp. . . . . *
Rives, Dyke & Co., Houston, Tex.
McCullough Tool Co. . . . . Sec. 1 — 8
R. P. Casterline, Los Angeles, Cal.
Mission Manufacturing Co. . . . . *
Rives, Dyke & Co., Houston, Tex.
Oil Base, Inc. . . . . *
Dozier-Eastman & Co., Los Angeles, Cal.
Oil Center Tool Co. . . . . *
Rives, Dyke & Co., Houston, Tex.
Otis Pressure Control, Inc. . . . . *
Dan Goodrich, Dallas, Tex.
Pelton Water Wheel Co. . . . . *
Edward A. Stratman, Huntington Park, Cal.
Professional Services . . . . . Sec. 2 — 2, 3
Reed Roller Bit Co. . . . . *
Brennan Advertising, Houston, Tex.
Ruska Instrument Corp. . . . . Sec. 2 — 1
Brennan Advertising, Houston, Tex.
Schlumberger Well Surveying Co. . . . Second Cover
Rives, Dyke & Co., Houston, Tex.
United Geophysical Co., Inc. . . . . *
Dozier-Eastman Co., Los Angeles, Cal.
Welex Jet Services, Inc. . . . . Sec. 1 — 30
Evans & Assoc., Fort Worth, Tex.
Western Geophysical Co. . . . . Sec.1 — 16
L. J. Swain Advertising, Whittier, Cal.

*In Previous Issues

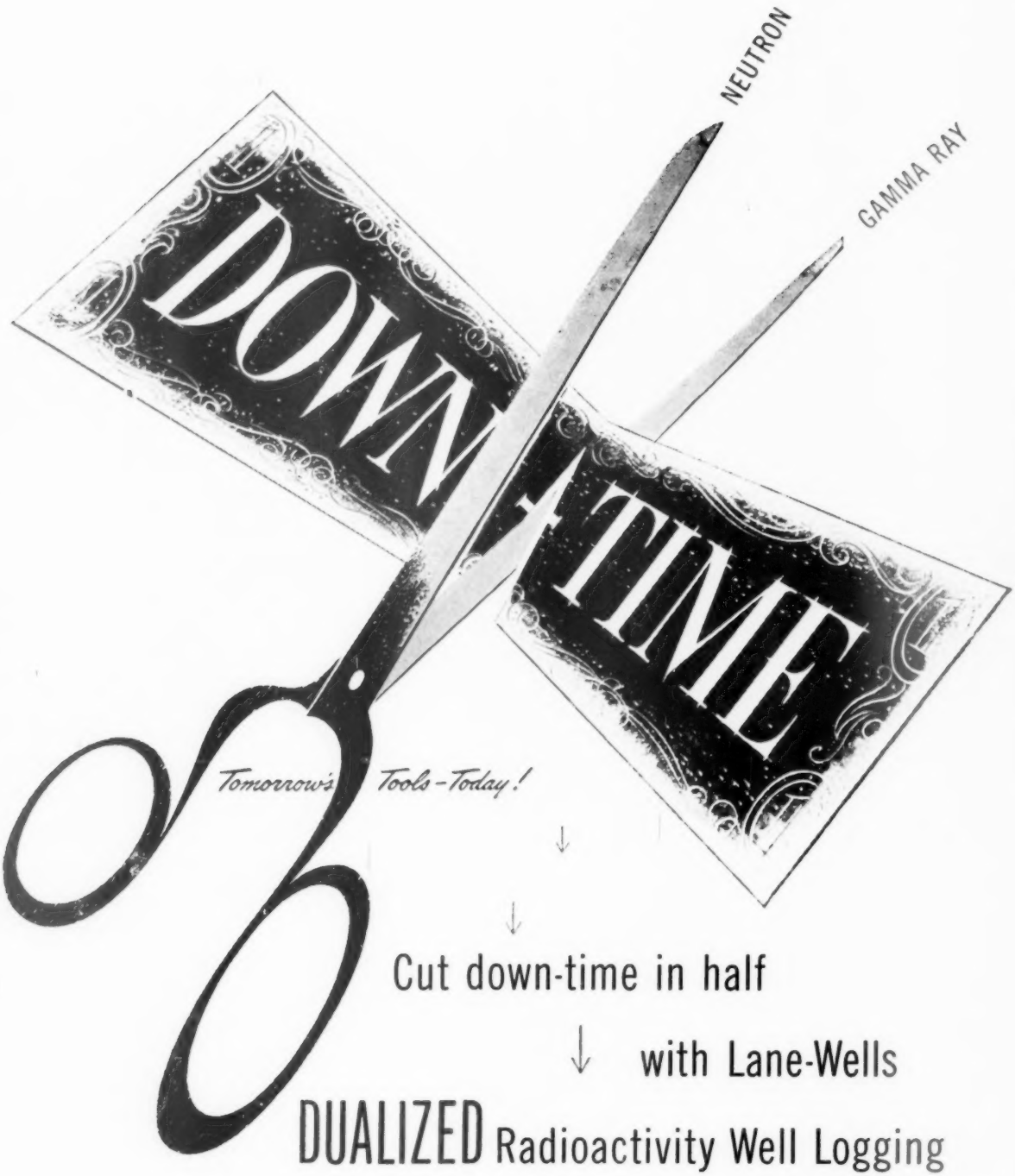
W7R – FIRST CHOICE FOR HARD ABRASIVE DRILLING

The popularity of Hughes "W7R" rock bits in hard abrasive areas is a matter of simple arithmetic. Their higher penetration rate and greater footage per bit mean more hole drilled faster *. . . and at a lower cost!*

That's why—in West Texas, the mountain states, and wherever hard abrasive formations are encountered, requiring maximum gage fortification—you find more Hughes "W7R" bits being used on more rigs than all other makes combined.

Experience gained in studying the performance of millions of bits in thousands of wells, over a period of more than 40 years, goes into every HUGHESbit.

HUGHES TRI-CONE® ROCK BITS



Cut down-time in half

with Lane-Wells DUALIZED Radioactivity Well Logging

Both Gamma Ray and Neutron Curves on a single run — same full detail, same sharp, repeatable curves. Available in a rapidly increasing number of areas. Ask your Lane-Wells man.

LANE WELLS COMPANY

General Offices, Export Office, Plant • 5610 So. Soto St., Los Angeles 58

LOS ANGELES • HOUSTON • OKLAHOMA CITY • LANE-WELLS CANADIAN CO. IN CANADA • PETRO-TECH SERVICE CO. IN VENEZUELA